TUNNELING BY MACHINERY.

DESCRIPTION

OF

PERFORATORS AND PLANS OF OPERATIONS

IN

MINING AND TUNNELING.

DEVISED BY

HERMAN HAUPT,

CIVIL ENGINEER,

FORMERLY BRIGADIER-GENERAL IN CHARGE OF THE BUREAU OF UNITED STATES MILITARY RAIL ROADS, AND CHIEF OF CONSTRUCTION AND TRANSPORTATION OF THE ARMIES OF THE RAPPAHANNOCK, VIRGINIA AND POTOMAC. CHIEF ENGINEER AND GENERAL SUPERINTENDENT OF THE PENNSYLVANIA RAIL ROAD, AND OF THE HOOSAC TUNNEL. PROFESSOR OF MATHEMATICS AND CIVIL ENGINEERING IN PENNSYLVANIA COLLEGE. AUTHOR OF GENERAL THEORY OF BRIDGE CONSTRUCTION, &C.

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Tunneling by Machinery.

DESCRIPTION OF APPARATUS

FOR

MINING, TUNNELING AND QUARRYING.

INVENTED AND PATENTED

By HERMAN HAUPT, Civil Engineer,

United States of America.

HISTORY OF THE INVENTION.

This invention is the result of more than ten years of experiment, attended with an expenditure of over fifty thousand dollars. The inventor is known in Europe as the author of the General Theory of Bridge Construction, published in 1851, and more recently of a second work on military bridges. He holds a very prominent position amongst the Civil Engineers of the United States of America, having been Chief Engineer and General Manager of the Pennsylvania Rail Road, and also Chief Engineer of the Hoosac Tunnel, the greatest work of the kind in the world, except that at Mount Cenis. During the recent war in the United States, he received a Commission as Brigadier-General, and was placed at the head of the Bureau of Military Rail Roads, having charge of the construction and operation of the numerous roads employed for government transportation.

General Haupt has had an experience of over thirty years as a Civil Engineer, during a portion of which time he occupied the Professorships of Mathematics and Civil Engineering in Pennsylvania College. He was educated at the National Military Academy of West Point, where he graduated in 1835, in the same class with General Meade and other officers of distinction.

In 1855, the inventor of this new mode of tunneling became connected with the Hoosac Tunnel, in the State of Massachusetts, a tunnel which was intended to be nearly five miles long without shafts, and designed to perforate the Green Mountain range at its base. His attention was at once directed to the construction of machinery for the purpose of drilling holes to be blasted afterwards with gunpowder. These experimental investigations were pursued by him at the very time when M. Sommellier and his associates were engaged in developing their machinery for the tunnel of the Alps, and with very similar results. Mr. Haupt's first machine, like that of Sommellier, consisted of a cylinder containing a piston to be worked by air, the cylinder moving forward on a stationary frame as the drill penetrated the rock with suitable mechanism for effecting the movements of feed and rotation.

Mr. Haupt was not satisfied with this machine; it was too complicated and too bulky; too many moving parts, and too much liability to derangement; he aimed at greater simplicity both in the machine itself and in the mode of mounting the drills. He sought to construct a drilling engine which should be very small, light, portable, compact, strong, cheap, not liable to derangement, easily repaired, so mounted as to possess great mobility, admitting of being placed and secured at any elevation, or at any inclination without loss of time, and lastly, that the space occupied by the whole apparatus should be so small that operations could be immediately resumed after a blast, without waiting to remove the debris which the explosion had detached.

These desirable and yet apparently incompatible conditions have been actually fulfilled, but the result was not attained immediately; as the history of the invention will exhibit.

In 1858, Mr. Haupt became acquainted with Stewart Gwynn, a mechanical engineer of considerable reputation, whose attention had been directed to the construction of drilling engines for submarine operations, the prominent feature of which was a hollow piston rod through which the drill passed.

Mr. Gwynn was employed by Mr. Haupt, as constructing engineer, who carried on his experiments at South Boston, in

developing a drill, the prominent features of which were, a stationary cylinder containing a piston, a hollow piston rod through which the drill rod passed, a slide valve, and a positive screw feed.

This machine was able to drill twelve inches in twelve minutes in hard granite, but Mr. Haupt, not being satisfied with it, and having conceived the idea of the *momentum feed*, commenced a new and independent series of experiments at Springfield, Massachusetts, to which he attended personally.

The experiments at South Boston, and at Springfield, were continued until June, 1861, when the suspension of operations at the Hoosac Tunnel terminated for a time the development of the drill.

The war at this time had commenced to assume gigantic proportions. The rail roads were found essential to supply the armies in the field. They were taken possession of by the Government, but confusion reigned supreme; a state of blockade was the normal condition, and the most vexatious delays were experienced in forwarding supplies.

In this dilemma, Mr. Haupt was recommended by members of Congress, as the only one known to them who was able to master the difficulties of the position. He was telegraphed for by the Secretary of War, and offered the charge of the Bureau of Military Rail Roads, with the title of Chief of Construction and Transportation, the position of Aid to the Commanding General, and the rank of Colonel. He accepted, and entered upon his duties. By a special order from the War Department his authority over the rail roads was declared to be supreme, and no officer however high his rank was to be allowed to interfere with his arrangements. Vested thus with the requisite authority, order soon succeeded chaos, and no delays or deficiency of supplies ever after existed during his administration of the Bureau.

A Commission as Brigadier-General was sent to Colonel Haupt in recognition of important services rendered in operations against the enemy during the second battle of Bull Run. He organized a Construction Corps, consisting chiefly of a few skilled mechanics, aided by a large number of negroes. A corps the remark-

able efficiency of which in constructing roads and bridges was the subject of general remark, and as General McDowell testified before an investigating committee, excited the surprise and admiration of foreign officers of distinction, who had never supposed such structures as he erected possible with the means and appliances used.

As was to be expected these labors in the military service caused a cessation of operations upon the drill. Nevertheless, this subject was kept steadily in view. In order to secure reliable assistance in perfecting his inventions, General Haupt apprenticed his eldest son to William Sellers & Co., of Philadelphia, where he became a very superior practical machinist.

In 1864, after Jacob B. Haupt became of age, the experiments on drills were resumed, and in a few months the momentum feed was developed and worked satisfactorily.

It would be interesting to a machinist to detail all the successive experiments and changes that the drill has undergone, but it is unnecessary. It will suffice for our present purpose to state that starting with a machine constructed on a similar principle and almost as complicated as that used at the tunnel of the Alps, it has now by successive steps in the direction of simplicity reached apparently the point of absolute perfection, a point at which no further improvement appears practicable or desirable.

Having reached this point in the construction of the drills, it was necessary to solve the problem of the best mode of mounting them, and the result will be given in the description of the stand or frame upon which the drills are placed.

Last year arrangements were made to test this machinery by a practical application to tunneling. A tunnel had been excavated in Pennsylvania to a distance of about one thousand one hundred feet, through a very hard conglomerate rock in the Coal measures. Arrangements were made with the Company owning the mine to finish this tunnel, and the necessary machinery was provided, but before it was put in operation the company failed, and the attempt was abandoned.

These experiments were prosecuted under the disadvantages of limited pecuniary resources. The State of Massachusetts never

contributed a dollar to the expenditures for these objects, and Mr. Haupt found himself compelled to raise funds from private sources, while carrying on the work of tunneling the Hoosac Mountain. The assistance from the State was insufficient to pay the cost of the work, and Mr. Haupt was compelled to provide capital, and also to defend himself against the incessant attacks of a powerful and influential, but at the same time a most bitter and unscrupulous opposition.

Perhaps the history of rail road enterprises throughout the world does not exhibit an instance of more extraordinary perseverance against difficulties of such magnitude as those which he encountered.

The brief historical sketch which has been given, seemed to be necessary as an introduction to the detailed description of the machinery. It was important to show that it was the fruit of many years of study and experiment, by an engineer of acknowledged scientific attainment, high professional position and long experience. As such it is entitled to the most careful consideration, and thorough investigation of engineers and miners in every country. The extreme simplicity and efficiency of the apparatus, its low cost, the direct application of the power and the rapid and economical progress as compared with any other mode of conducting such operations must revolutionize mining and tunneling throughout the world, and render practicable gigantic operations in engineering, which without such means would be classed with the impossible.

DESCRIPTION OF GENERAL HAUPT'S ROCK DRILL.

In drilling rock by hand three movements are observable. 1st, a reciprocating or back and forward movement; 2d, a rotation; 3d, a feed or progression, as the drill penetrates.

A machine to accomplish the same object must have the same movements, and the best drill is the one which accomplishes them all in the most simple manner, with greatest certainty, with least liability to derangement, and with the smallest expenditure for repairs.

Numerous attempts have been made to construct machine drills,

but it is believed that the drill of M. Sommelier at Mount Cenis, has been heretofore the nearest approximation to success.

The length of the Mount Cenis drill is one hundred and six and one-third inches, its weight between six hundred and seven hundred pounds, too great to be handled except by machinery; its length permits holes to be drilled only in directions nearly parallel. Its parts are numerous, its liability to derangement great. The cost of repairs so considerable that the expense of tunneling exceeds the cost by hand labor. A section of the Mount Cenis drill on a scale of one-eighth the full size is given in Plate 1, Fig. 1.

The extreme length of General Haupt's drill, Plate 1, Fig. 2, is only thirty-two inches, considerably less than one-third the length of the Mount Cenis drill; it can be turned in any direction whatever; two machines on the same stand can at the same time drill holes in directions nearly at right angles to each other. It weighs about one hundred and twenty-five pounds, and one man can lift it, handle it, or walk away with it. Its parts are so few and simple that it seems certain that no improvement can ever be made to reduce the number of parts even to the extent of a single piece, and yet it contains all that are required for the movements. It is not liable to derangement. The wearing parts are inexpensive and easily renewed; every part is accessible for oiling. Any one drill can be removed and another inserted without stopping any other machine. The drilling tools are inserted at the back and not at the forward end; a minute is sufficient time to take out one and insert another. The cost of tunneling is expected to be so much less than the cost by hand labor, that a company has recently been organized in the United States to take contracts for tunneling at the cost of hand labor, who expect to make very large dividends from the profits. The outlay for machinery and power on General Haupt's system, with the direct application of steam is not one-tenth of the expenditure required on the Mount Cenis or Hoosac plans, as will be more fully explained hereafter.

We propose now to explain the construction of General Haupt's drilling engine, next the mode of mounting it, then the power and its mode of application, and lastly, the application of

the whole to tunneling, with a description of the arrangements for manipulating the drills and the system of ventilation.

It has been stated that a drilling engine for perforating rock requires three movements:

1. A reciprocating movement.
2. A rotative movement.
3. A feed movement.

THE RECIPROCATING MOVEMENT.

The reciprocating movement in nearly all drilling engines is produced by the to and fro motion of the piston. The points to be determined in connection with this movement are the diameter and stroke of the cylinder and the form of valve.

If the drilling tool is connected with the piston and the blow upon the rock is given by the direct action of air or steam, the pressure per square inch being assumed, the diameter of cylinder necessary to secure any given total pressure is readily determined; a diameter of cylinder of four and one-eighth inches with a piston rod of two and one-quarter inches, will leave an annular ring of nine and four-tenths square inches for the power to act upon; a pressure of sixty pounds per square inch will give a total force upon the piston of five hundred and sixty pounds, and this is found to be sufficient to strike a blow as hard as the steel used in the drill points can stand.

The force of the blow is almost entirely independent of the length of stroke, and it therefore follows that the stroke should be as short as will fulfil the other essential conditions of moving the valve, rotating and feeding. For these purposes four inches is found to be a convenient length, and the capacity of the cylinder is determined to be four and one-eighth inches diameter and four inches stroke; allowing a breadth of piston of two and a half inches, and a small space for clearance at the ends, the inside length of cylinder is about eight inches. Drills constructed with larger cylinders involve a very great and unnecessary waste of power. At each stroke two cylinders of steam or air must be expended. The travel of a piston per minute should not exceed a given number of feet, whether the stroke be long or short, con-

sequently any increase in the length of stroke must diminish the number of blows per minute with a given velocity of piston.

Assuming two hundred and fifty feet per minute as the proper velocity of piston, the travel at each stroke will be eight inches, and the number of blows per minute three hundred and seventy-five. If a stroke of ten inches should be given as in several drills that have been constructed, the number of strokes with the same velocity of piston would be reduced to one hundred and fifty per minute.

The expenditure of steam or air at each stroke is ninety-four cubic inches, and per minute twenty cubic feet.

At sixty pounds per square inch in addition to the pressure of the atmosphere, the temperature of steam would be three hundred and eleven degrees of Fahrenheit, the volume as compared with water, as 383. to 1, and consequently the quantity of water to be evaporated per hour for each drill would be three and thirteen one-hundredths cubic feet.

As one cubic foot of water evaporated per hour is equivalent to one horse power, the boiler or reservoir capacity must be sufficient to furnish three and thirteen one-hundredths horse power for each drill.

Estimating the actual power upon the piston as five hundred and sixty pounds, traveling over a space of two hundred and fifty feet per minute, the performance of the drill engine would be equivalent to one hundred and forty thousand pounds raised one foot, or about four and one-quarter horse power.

If the stroke should be ten inches instead of four, and the number of strokes per minute be supposed the same, the actual effect would not be increased, but the expenditure of steam or air would be seven and eighty-two one-hundredths cubic feet per hour or nearly eight horses power.

The propriety of a short stroke must therefore be apparent.

VALVE.

For ordinary crank engines the slide valve is well adapted, but for drilling engines, the ordinary form is seriously objectionable. Whatever may be the mode of connection between the piston rod

and valve, the opening into the cylinder must be by a gradual sliding movement which opens the port for the admission of air or steam into the forward end of the cylinder before the stroke is fully completed, and the blow given upon the rock. It is obvious therefore, that the steam or air is entering and retarding the velocity of the piston at the very point where it should be greatest. If under these circumstances a blow is given of sufficient force to be effective, it must be secured by a wasteful expenditure of power to compensate for the retardation caused by the slide valve.

The Gwynn drill, the Mount Cenis drill and all others known to the writer, excepting the one under consideration, is defective in this particular. To overcome the difficulty, Mr. Haupt designed and patented a balanced spring valve, the operation of which will be explained.

The arm which moved the valve was not connected with the piston rod, but was operated by springs; each movement of the piston in either direction would set one spring and upon reaching the end of the cylinder would touch a trigger and release the spring at the opposite end, shifting the valve by an instantaneous movement, but not until the stroke had been completed. The present valve is more simple, and operates in a similar manner, the chief object being to allow the piston to complete its stroke before the valve is shifted.

The form of valve now used is shown in Fig. 3, Plate 1. It is nothing more than a piece of pipe on which four rings are shrunk and accurately turned to fit the cylindrical steam chest in which it moves; the two middle rings open and close the ports precisely as in a slide valve when its position is shifted.

If this valve had a rigid connection with the piston rod, it would be a balanced slide valve moving with very little friction, but possessing no other advantage; but the rod which moves the valve is not rigidly attached to it; it terminates in a piston in the middle of the tube on each side of which are spiral springs, held and compressed by rings screwed into the ends of the tube. When the stops on the valve rod are struck by the arm on the piston rod, the effect is not immediately transmitted to the valve, but the

spring yields to a certain extent to the blow before the inertia and friction of the valve are overcome. This gives the piston power to travel some distance after the stop is struck before its motion is retarded by the admission of steam.

THE MOST PERFECT FORM OF VALVE.

The valves previously described have given very satisfactory results as compared with any of the original forms, but there is still an objection. When the steam is first admitted into a cold cylinder a portion of it is condensed and forms water which resists motion; if the valve is not at one end or the other of its stroke, it becomes necessary to move it by striking with a block, and this must be several times repeated, sometimes requiring half a minute before the water is all forced out through the exhaust passages, and the machine works regularly and continuously.

It is proper to observe here that the cylinders are not furnished with relief cocks as in other engines, as it is not expedient to allow any escape of steam into the tunnel, and there is no difficulty in expelling the water of condensation through the exhaust passages.

The perfection of a valve for a drilling engine would be one which would fulfil the following conditions:

1. A balanced valve requiring but little power to effect its movement.

2. A valve that will always be in such position as to leave one of the steam ports open so that the engine will start without difficulty, delay, or moving the valve by hand whenever steam is admitted.

3. A valve which will not open to admit steam at the end of the forward stroke so early as to retard the force of the blow, but when the blow is given will shift instantly to admit steam for the back stroke.

All these conditions are fully complied with in a form of valve recently designed by Mr. Haupt. It is represented in Fig. 7, and consists of the following parts: A tube or rod, 1.11, sliding within a cylindrical steam chest, and surrounded by rings which fit tightly, and form the rubbing surfaces of the valve.

A valve rod passing through a gland at the forward end of the steam chest, and connected with the valve either in a rigid manner or by the interposition of springs to relieve the blow upon the end of the steam chest. A stop on the valve rod so adjusted that when the arm (2) or the piston rod is at the end of the back stroke, it will place the valve in proper position, with the spiral spring (4) around the valve rod compressed, and the valve fastened by the trigger (5) which is pressed down by the spring (6).

The trigger (5) has upon it two adjustible stops, which can be placed in such position as to shift the valve at the proper part of the stroke. When the arm (2) commences to move forward, it has no effect upon the valve rod, which remains fastened by the first stop, but when the arm (2) reaches the second stop (7), the trigger is raised, the spring relieved, and the valve rod instantly projected forward by the recoil of the spring. As the stop (7) is adjustible, the length of stroke may be regulated at pleasure, but the expenditure of steam will not be reduced by shortening stroke, unless a portion of the spaces at the ends of the cylinder be filled with solid material, or the piston lengthened.

This valve appears to fulfil perfectly every condition desired, and to leave no room for improvement.

ROTATION.

There are several modes of effecting the rotation of the drill, but they are nearly all some modification of a ratchet, with a pawl moved by an arm or projection sliding on an inclined surface. Instead of a ratchet, a strap may be used, so arranged as to tighten when the arm to which it is attached moves in one direction, and loosen when it moves in the opposite.

The rotation could also be given by means of an arm attached to a fixed point, and connected with the pawl which moves the ratchet by a universal joint. Experience proves that, in order to secure a positive and regular rotation, one ratchet is not sufficient; there must be a second ratchet, or at least a second pawl connected with some non-rotative point, to prevent the drill from turning in the wrong direction, and losing on the forward stroke the rotation given on the back stroke.

In Mr. Haupt's drill with the momentum feed, the rotation is accomplished by the mechanism represented in Fig. 4. The gripper box which holds the drill rod, and rotates with it, is cut on its circumference with teeth, the position of which is marked 5.5; a ring (6) carries a pawl which engages the teeth of the ratchet. To the ring (6) is attached a projection or stud, which moves in an inclined slot in the outer case 7.7.

To hold the rotation thus given, a second ratchet is cut on the projecting edge of the gripper box at 2.2, and against this ratchet is pressed a pawl in the form of a piece of steel five inches long, contained in a box or recess on the side of the case marked 3. This piece of steel acts as a guide, and allows the drill to rotate freely in one direction, but engages the teeth of the ratchet, and prevents any motion in the opposite direction.

In the second form of drill represented in Figs. 2, 5, and 6, the outer case at the rear end is dispensed with, and a guide (1, Fig. 6) upon the front end is substituted. This guide supports the arm (2) which moves the valve, and is also provided with a spiral slot, through which passes a stud (4) carrying a pawl which moves the ratchet (3).

In this form of drill only a single ratchet is required, but there are two pawls, one in the stud (4) to effect the rotation, and the other in the arm (2) to prevent slipping.

The arm (2) with the rings which embrace the piston rod may constitute but a single piece, and enclose the ratchet in such a manner that to become loose would be impossible, but in two pieces its construction is less difficult.

The ratchet is firmly attached to the piston rod, and secures the rotation by turning it, and with it the box which holds the feed nut at the rear end of the cylinder, which box is also connected with the drill holder by a feather in the box sliding in a groove in the tool holder, thus securing a positive rotation.

In this drill the number of parts is reduced and the construction simplified.

THE FEED MOVEMENT.

Of the three movements required in drilling rock, the feed

appears to have presented the greatest difficulty to inventors, and the drill now under consideration appears to be the only one in which these difficulties have been overcome in a manner entirely unexceptionable by devices at once simple and effectual.

The conditions of feed necessary for a perfect machine are, That it shall be automatic; not dependent in any manner upon the attention of the operator.

That it shall be self-adjustible and variable, feeding with precision as fast as the tool has power to penetrate the rock, but no faster; varying its feed in the same hole with the varying hardness of the rock, or sharpness of the point.

The feed in the Sommellier drill is a very peculiar one. The cylinder is comparatively long, and the piston does not at each stroke traverse the entire length of the cylinder, but gradually approaches the forward end as the drilling tool penetrates the rock. When the forward end is nearly reached, a trigger arrangement is touched, which by the recoil of a spring that has been gradually wound up, throws the cylinder forward a certain distance, and brings the piston again to the rear end of the cylinder.

This exceedingly complicated arrangement involves many serious disadvantages. Whatever may be the length of stroke, two cylinders of air or steam must be consumed at each movement, and if the shortest stroke is sufficient to give an effective blow, any increase in the length of the cylinder must involve a waste of power. This would be no disadvantage where there was an excess of power, and air was required for ventilation, but it would be preferable to provide it in some other way.

The variable position of the piston in the cylinder renders it difficult to work the valves by the simple device of an arm and tappets, and a separate and independent cylinder is introduced for the purpose of working the valve, involving great complication in the mechanism, as will be apparent by comparing Figs. 1 and 2 of Plate 1, which are drawn to the same scale of one-eighth full size.

Other drills have been constructed in which the feed was given by means of a fixed nut attached to some part of the machinery, usually the rear end of the piston rod. The drill holder passed

through this nut, and carried a screw on its outer surface. As the drill was rotated by the mechanism provided for that purpose, it was fed forward through the nut at a uniform rate of progress.

The objection to this device was, that no uniform feed could be adapted to a variable rock, and in a uniform rock, if the feed should be too rapid, the stroke would shorten, the valve would not be shifted, and the drill would stop. The same difficulty would occur when the cutting edges became blunt. If on the contrary the feed should be too slow, the effect produeed would not be in proportion to the power expended.

To overcome these difficulties, numerous attempts have been made to secure a variable feed. The mechanism consisted in a spiral thread around the tool holder, and a nut through which it passed; the nut being turned by a separate ratchet, independent of the regular rotative movement of the drill, would feed the drill holder a certain distance at each partial rotation.

To render this mechanism self-adjusting, a provision was made that if the drill advanced faster than it could penetrate the rock, the feed ratchet would cease to act, while that which produced the rotation would continue, the two being entirely independent of each other in their movements.

This was very beautiful in theory, but the difficulty was that it would not work in practice, and the cause of the failure is easily explained.

At the forward end of the stroke, a ring or projection on, or moving with the piston rod, came in contact with the end of a lever, the opposite end of which carried the pawl which turned the feed ratchet. If the stop did not come in contact with the end of the lever, there could be no feed, and this would be the case whenever the feed was too rapid for the penetration of the drill; but here lay the difficulty; the feed was necessarily given at the instant when the point of the drill was in contact with the rock at the end of the forward stroke, and consequently when it was impossible to screw it forward without great violence to, and strain upon the feed apparatus; nothing did stand, and nothing

could stand such strain; breakages were incessant, and after much loss of time and money, the machines were abandoned.

In neither of the forms of drill designed by Mr. Haupt does this defect appear; the feed is given either before the point of the drilling tool touches the rock, or after it has left it on the back stroke, as will be shown in the description.

MOMENTUM FEED, OF H. HAUPT.

The principle of the momentum feed may be illustrated in a familiar manner. If a person should be driving rapidly in a vehicle which should be suddenly checked by coming in contact with an obstruction, he would be thrown forward with violence. So also if a drilling tool should be held in such a manner that the tool holder could be suddenly checked, while the tool itself could move forward, a progressive forward movement would be the result each time that the check was given.

Such a check to the momentum of the tool holder would of course diminish to some extent the force of the blow upon the rock, but if this check should only be given at intervals, the loss of effect would not be serious, and even at such times the blow would be heavy from the momentum of the drill rod itself, the velocity of which is but slightly retarded.

The mechanism for effecting this movement is represented in Fig. 4, the parts of which will now be described, and the mutual action explained.

1. Represents the stud which moves in a spiral slot in the case 7, to rotate the drill.
2. A ratchet on the gripper-box to prevent rotation in the wrong direction.
3. A steel guide and pawl pressed against the ratchet 2 by a spring to hold it in position during the forward movement.
4. Box bolted or riveted on 7 to contain 3.
5. Ratchet cut in gripper-box, to effect rotation.
6. Ring which carries pawl, and which is moved by the stud 1, to effect rotation.
7. Cylindrical case bolted on end of steam cylinder which protects the working parts and carries the guides for the ratchets.

8, 8. Line of rear end of steam cylinder.

9, 9. Anvil or stops which coming in contact with projections 18, on face of gripper-box 11, detaches the drill rod and gives a feed.

10. Gum ring interposed between the anvil and the end of the cylinder to relieve the concussion.

11. Gripper-box containing the wedge-shaped pieces or grippers 15, which hold the drill rod 17.

12. Collar on end of piston rod.

13. Volute spring interposed between the collar 12 and the grippers 15. When the motion of the gripper-box is checked by coming in contact with the stops 18, the drill rod 17 moves forward, the spring is compressed, and the grippers are pushed backwards over the rod, taking hold at another point back of the first, and thus giving a forward feed.

14. Washer which is beveled to prevent the grippers from falling out when the drill rod is removed.

15. Grippers to hold drill rod, the surfaces of which as also of the drill rod may either be smooth or ridged. If smooth the surfaces must be free from grease or the adhesion will not be sufficient to prevent the drill rod from slipping backwards and thus losing the feed.

16. Follower which by being screwed into the back end of the gripper-box compresses the spring 13, releases the grippers 15, and permits the drilling tool and holder 17, to be readily withdrawn from the rear end without interfering with the work of any other machine.

17. Drill holder.

18. Projections of about one-third of an inch on the gripper-box, which coming in contact with the anvil or stop once or twice in a rotation produces the feed.

The three diagrams A, B, and C, all refer to Fig. 4, and the corresponding parts have the same numbers.

It will be perceived from this description of parts that the feed is given by the projections on the gripper-box coming in contact with the stops on the cylinder head; this causes the drilling tool to be projected forward until it strikes the rock when the recoil

of the volute spring forces the gripper pieces which have been thrown forward back into their places, and they grasp the drill rod further back than before the concussion. The force of the blow is relieved by the gum ring and the pieces which receive the blow are easily detached and renewed; they are made quite hard and do not wear or batter rapidly.

It will be perceived that this feed is perfectly self-adjusting, and that it is given before the drilling tool comes in contact with the rock; consequently the strain referred to as a fatal objection to other contrivances for feed is avoided.

HAUPT'S SCREW FEED.

Although the momentum feed performs well, and none of the parts connected therewith have broken in any of the experiments that have been made for a long time, it is completely eclipsed by one of those extremely simple and beautiful contrivances which when discovered excite surprise that any other mode of accomplishing the movement should ever have been thought of or employed.

Although the attempt to feed at the end of the forward stroke by the rotation of a nut proved a failure, no one but Mr. Haupt appears to have conceived the idea of giving the rotation to the nut on the back stroke, or if the necessity was discovered, the means of effecting the movement were not perceived.

Nothing could be more simple than the mechanism by which this very important result is secured. It consists simply in allowing the forward movement of the piston instead of rotating the nut directly, to compress a spring which on the back stroke produces the rotation by its recoil, and thus gives the desired movement at a time when there is no strain whatever upon the parts.

Fig. 8, diagrams A, B, C, illustrate this movement.

1. Represents the drill holder passing through the hollow piston rod 2, and the nut 3.

3. The nut 3 contains a square thread with a pitch of about one-fourth of an inch, fitting a similar thread around the drill holder 1.

4. A metallic box enclosing the nut on all sides; this box is in two halves opening with hinges at 5. 5.

6. A ring which carries a projection sliding in a spiral groove in the box 4; by slipping on the ring and then turning it, the two halves of the box are drawn lightly together and securely clamped. By taking off the ring, the box is opened and the nut and rod immediately withdrawn. The nut can be made in halves if desired, but it is not necessary.

7. A ratchet cut around the projecting edge of the nut 3, which is rotated by the pawl 8, and held by a spring *s*.

8. A pawl attached to and working in a recess in a rectangular piece of steel 9; this piece slides in a recess in the box 3, and carries a rack working into the teeth of an arc on the bent lever 10.

10. A solid lever with the arms nearly at right angles, and the fulcrum around a stout pin in the side of the box 4.

11. A rod projecting forward from the box 4, and terminating in an adjustible knob by which the length is regulated. When this rod comes in contact with the end of the cylinder, the other end acts on the lever 10, raises the pawl 8, which slips over the ratchet 7, without turning it. At the same time a very stiff spiral spring 12, is forcibly compressed. On the back stroke the spring reacts, pulls the pawl, and rotates the feed nut.

The parts are so proportioned and adjusted, that the pawl may engage one, two or three teeth, or none at all, according to the feed. If the drilling tool feeds forward too rapidly, the movement of the rod, and the throw of the ratchet are lessened, and a perfect compensation is secured, thus fulfilling every condition of a perfect self-acting and self-adjusting movement.

MODE OF MOUNTING THE DRILLS.

The satisfactory prosecution of mining or tunneling operations requires not only that a drill or perforator should be provided, that is applicable to the purpose, but it must be so mounted as to permit its convenient use.

The conditions to be fulfilled in mounting the drills are,

1. That the plan adopted shall admit of the erection and removal of the drills in the shortest possible time.

2. That it shall permit the resumption of drilling operations as quickly as possible after a blast, so as to secure the greatest number of blasts in a given period of time, the progress being in proportion to this number.

3. That the drilling of the holes should interfere as little as possible with other operations, especially with the removal of the debris.

4. That the most perfect mobility should be secured, admitting of drilling in any position, at any angle, or at any elevation.

5. That the adjustments of the drills, and the fastening of them in any desired position, should require the least possible period of time.

6. That the manipulation should be effected with the smallest number of attendants.

7. That if any drill should break, another can be inserted without delay, and without stopping any other machine.

The Mount Cenis drills are mounted on an iron frame of considerable size and weight, which is supported on wheels, and runs forward upon a rail road track. The perforators can be moved horizontally or vertically, on arms which admit of these motions, but their extreme length does not permit holes to be drilled at an inclination varying much from the direction of the gallery.

The machine is so large, and the spaces on each side consequently so small as not to permit the convenient removal of the debris when the perforators are at work, consequently there is considerable delay in resuming operations after a blast, independently of that which is caused by the defective system of ventilation. In consequence of these difficulties, it has been found practicable to blast only two or three times in twenty-four hours.

In the experiments made by, or under the direction of Mr. Haupt, several modes of mounting drills were tested. The frames which supported them consisted of one, two, or four columns, each column placed vertically, and carrying stout screws, with steel pointed head at both ends. The support was derived

from the top and bottom rock, into which the points were firmly screwed.

The stand with a single column did not afford the drills a sufficiently firm support, and it was soon succeeded by one with two and afterwards with four columns.

Plate 2, Fig. 1, represents a stand containing four drills mounted for use; the total height is six feet. There were eight large screws like jack screws, two in each column, which were forced into the rock at top and bottom, and secured by jam nuts to prevent loosening.

The support of each separate machine consisted of trunnions cast on the sides of the drill cylinder. These trunnions rested in sockets clamped to slotted pieces, which moved vertically along the columns, and were secured by screws.

The trunnions permitted a rotation around a vertical circle, while the slotted pieces on the sides allowed a horizontal movement of about twenty degrees.

One of these columns was used as a steam pipe, another to carry away the exhaust. The connections with each drill were by means of pieces of rubber hose, as shown in the figure.

Sixteen of these drills and five stands were constructed for use in a tunnel in Pennsylvania in the fall of 1865, and some experiments made with them; but owing to the suspension of operations, in consequence of the failure of the company, no regular work was done. The experiments, however, were of great value, from the facts and the experience which they furnished.

It was found that there were too many screws about the drill stand. Eight screws required to be pressed against the rock to hold the stand, followed by jam nuts to keep them tight. Sometimes these screws had to be run out to an inconvenient length, or blocking had to be resorted to. Then again too many small screws required to be turned to place each drill in position, and although the time required for each screw was small, the aggregate was considerable, involving too much loss of time.

Another practical difficulty was found to exist in the use of two of the columns as steam pipes; the men in moving the stands would frequently grasp the hot pipes instead of the cold ones,

and from this cause there was a liability to accident by letting the stands fall.

A careful consideration of all the inconveniences found to exist in the use of the four column stand, as originally constructed, has led to the substitution of keys or wedges, instead of screws, wherever practicable, and the final result of many improvements is exhibited in the stand with two columns, represented in Figs. 2 and 3, Plate 2.

Instead of four set screws at the bottom, the base rests on a cast iron tripod (1), in which are three steel points, which, by means of a ball and socket joint (2), accommodate themselves to the inequalities of the surface, and require no adjustment whatever. The base is hollow, and divided by a transverse partition into two apartments (3, 4), into one of which the live steam is admitted, and into the other the exhaust. The connections of the steam and exhaust pipes are shown in Fig. 3.

The top of the base is shown in Fig. 4 with the position of the three steam connections and globe valves (5), and the three exhaust connections (6) which require no valve.

On the base the two columns are placed, and attached by means of a screw cut on the outside of the column, or by rivets. The most convenient mode of attachment is by casting projections on the base, over which the columns can be placed and secured by riveting.

The size of the columns should be about four inches exterior diameter, the thickness three-eighths of an inch, and the material wrought iron.

The connection at the top is by means of a strap (7) two inches deep, three-quarters of an inch wide, with rings (8) to embrace the columns tightly. To obviate the loss of time and the instability which result from too great length of the top screws, a second tube is provided to slide inside the column, like the tube of a telescope (see details, Fig. 5). This tube may be extended a foot or eighteen inches at one movement, and held by a pin (9) which passes through holes in the column, and upon which the bottom of the inner tube rests.

The inner tube at its top end carries a nut (10) to which it is

riveted, and through this nut passes the steel pointed set screw (11), secured when in place by a jam nut (12), or by passing a rod through the holes in the screws of the two columns, which furnishes a convenient mode of locking them.

Each stand may contain three or four drills, but three is a convenient number in driving a tunnel gallery six feet high. The distance between the columns of each stand is ten inches, or eighteen inches from out to out. The number of stands in use will depend upon the width of the gallery. In a heading six feet high and fifteen feet wide, it might be expedient to use four stands mounting twelve drills, in order to secure the most rapid progress possible; but two stands with six drills would give very satisfactory results, as two or more sets of holes could be drilled before blasting.

Each drill is mounted on a cross bar (12; see details, Figs. 1, 3, 6, 7), attached to the columns by means of clamps (13).

These clamps are made in two symmetrical halves, cast from the same pattern. A projection in front carries the bar (12), which is secured by keys on each side of the clamp. (Fig. 6.) The back part of the clamp is circular in section, and a ring screwed around it holds the parts together securely. (Fig. 6, B.)

To prevent movement, a block or clamp piece of iron or brass (16), fits in a recess in the clamp (17), the inner surface of which is curved to fit accurately the surface of the column with which it is in contact. It is pressed tightly against the column by means of a key (18) driven behind it, and in a direction at right angles to the direction of the clamp piece. The keys are all wired (20), and the clamp pieces notched so that, when loose, none of them can fall out, or be removed without taking out the wire. The ring which is screwed on to connect the two halves of the clamp has notches on opposite sides through which the key passes, so that the key not only presses the clamp piece firmly against the column, but at the same time holds both it and the ring in place, so that neither can be removed.

This description of the clamp which supports the forward end of the drill will also answer for that which supports the rear end.

(Fig. 8, A and B), except that the latter must have an eye (14) through which the brace rods (15) are passed.

These clamps are also cast in two symmetrical halves, but, instead of the ring to hold them together, there is at the rear end a cap containing a hole through which the brace rod passes, and an independent clamping arrangement, similar to that already described, to hold this rod. The cap serves as a swivel, and is prevented from unscrewing by the rod which passes through it. The keys are placed at right angles to the clamp pieces and to the rods, in which position the jarring, pulling, or pushing on the rods will have but little tendency to loosen them.

A third form of clamps, represented in Fig. 7, connects the drill cylinder at its forward end with the cross bar which supports it. A plug is screwed into the cylinder, which passes through a hole in the clamp, and is secured by a key. A recess in the cylindrical part of the clamp also admits a key to fasten it on the cross bar.

To hold the drill when at work, especially in commencing a hole, two points of support are necessary; after the drilling tool has penetrated a few inches, the hole itself affords a firm support. The cross bar (12) holds the forward end of the drill cylinder, and the brace rods (15) passing through the eyes of the clamps hold the rear end. These brace rods are about ten inches long; they are straight and round, three-quarters of an inch in diameter; they are connected with the cylinder by means of an eye (20; Fig. 9), which passes over a pin (21) screwed into the end of the cylinder. The eye is prevented from slipping off by means of a wire through the end of the pin. The rod is furnished with a universal movement by means of the joint (22) in connection with the eye (20).

All the parts connected with the support and movement of the drill upon the stand have now been described; it remains to explain the manipulation required to place the drills in position.

It will be observed that there is not a single screw connected with any of these movements; that keys have been substituted in every instance; that the keys are placed in a direction at right angles to the direction of the jar or strain, so that there is but

little tendency to rattle loose; that every clamp piece has a transverse notch, through which the key passes; and that every key is wired.

The advantage of effecting the adjustment by means of keys, instead of screws, became evident after a short course of experiments at the Franklin tunnel. The screws required to be turned in effecting the adjustment were not all of the same size; wrenches had to be adjusted to fit. Sometimes they would be mislaid, and time lost in looking for them. The annoyance from this cause was considerable; those who experienced it can appreciate the advantage of a system in which all the fastenings can be loosened in a few seconds by three or four light taps with a hammer, or a stone if the hammer is mislaid, and tightened again as readily.

As the distance between the columns is ten inches, while the width of the drill cylinder is six inches, and its length ten, there is a play of four inches to the right or left, and as the point of rotation at the forward end is about four inches in advance of the line of the columns, the rear end of the cylinder when placed on one side will swing clear of the column on the other side. This will admit of a range of horizontal movement exceeding ninety degrees; a degree of mobility never before approached in any previous system of mounting, and impossible with any other than a very short machine.

In a vertical direction there is no limit to the movement; the drills may be placed at any angle, from vertical upwards, to vertical downwards.

As the drill cylinder can be placed in contact with either column, it is possible to work as closely to either side of the tunnel as may be necessary. A narrower stand would possess no advantage in this particular.

To shift the position of a drill, it is not generally necessary to move the forward pivot; it is only required to loosen the two column clamp keys, and the two rod clamp keys to secure a movement both horizontal and vertical. Less than a minute should suffice for this adjustment.

The gum pipes which carry the live and exhaust steam to and

from each drill are not disconnected, except when a drill is to be sent to the shop for repairs; they remain attached to the drills, and stand and do not interfere with the movements.

If a drill point should break or become so dull as to require sharpening, the box at the rear end which holds the feed nut is thrown open, the drill rod with the nut attached is drawn out and another rod and nut inserted; there is no necessity for losing time to back the drill rod out by unscrewing the feed nut as in other drills.

If it should become necessary to remove one of the machines from the stand and substitute another, this too is very rapidly effected. The key in the plug at the forward end of the cylinder must be knocked out, the wires removed from the pins at the rear end, and the hose disconnected. As the hose couplings are made upon an improved plan without screws, the whole operation is performed with great celerity. All the couplings of pipes and hose are connected by simply pressing them together with the hand and disconnected by pressing a spring and pulling them apart.

For the rapid prosecution of mining and tunneling operations, it is not sufficient that the engineer should be provided with a large number of perforators properly mounted so as to secure the requisite mobility and facility for adjustment. These are of course primary considerations; without a perfect drilling engine everything else would be useless, but even with it there are many auxiliary appliances upon which the rapidity of progress essentially depends.

In ordinary tunneling, the most difficult portion of the labor and that which consumes the most time consists in drilling the holes for the blasts. At the Hoosac Tunnel where accurate records of all the operations have been kept by statisticians employed for the purpose, it appears that the average progress in drilling by hand in the talcose slate rock, a rock of average hardness, is forty-six inches per day, of eight hours, or about ten minutes to an inch. In the same rock the machines should readily drill at least two inches per minute.

The substitution of machine for hand labor in drilling is there-

fore very important, if other essential conditions can be also complied with; these are,

1. A mode of erecting, applying power, and removing the drills expeditiously.

2. Facilities for resuming drilling operations immediately after a blast without waiting until the material blown down has been removed on cars, and without interfering with its removal.

3. Ample power for operating the drills.

4. Perfect ventilation at all times.

Other conditions of accelerated progress which may be considered secondary are,

5. A convenient mode of furnishing light.

6. A convenient mode of maintaining the alignment and grade.

7. The best mode of loading and blasting holes.

8. The most safe and powerful explosive agent.

9. The best mode of protection against stone projected by the blasts.

These subjects will be considered in the order in which they have been stated.

MACHINERY TO AID IN ERECTING AND REMOVING THE DRILLS.

The drills used at the Mount Cenis Tunnel weigh about six hundred pounds, and the latest form of drill constructed for use in the Hoosac Tunnel weighs according to official reports, three hundred and seventy-two pounds. The weight of Mr. Haupt's drill is about one hundred and twenty-five pounds, and the stand one hundred and eighty. Three drills mounted with stand would weigh about six hundred pounds. This is a very manageable weight; six men, three on each side would find no difficulty in carrying a stand with its attached drills without any machinery whatever, and a single drill could be readily lifted to change position, or carried away for repairs by one man.

These are great advantages over heavier forms of drilling engines; nevertheless, to avoid manual labor as much as possible, several plans for handling the stands were devised. The one to which a preference has been given, was suggested by Mr. E. C. Smede, one of the principal assistant engineers in General

Haupt's army construction corps. This apparatus is represented in Plate 3, Fig. 1, and consists of a low car with wheels twelve or fourteen inches in diameter. The floor should be level with the top of the axle. The gauge of the track forty inches, which is the usual mining gauge in Pennsylvania, and as it is sufficiently wide, there is no necessity for adopting any other. On the floor of the car is laid a circular track on which the two wheels of the trussed lever revolve. A center pin keeps the wheels on the circle. The trussed lever is about twenty feet long from the center to the forward end, and fifteen feet at the rear end; at the top are two ties of angle iron which also serve as rails for the wheels of the small roller which carries the counter-balance weight. Four braces support the ends, and form the truss.

At the forward end is a swivel, from which is suspended two short pieces of chain, with hooks to clamp the columns, and grasp them at any point. The counter-balance weight is run out by means of the crank, to a sufficient distance on the short arm, to balance, or nearly balance the weight of the drill stand. The angle iron is pierced with holes, and a pin holds the weight in any position; when the stand is laid on the car, the counter-balance weight is then rolled to the centre, when the lever can be removed from the stand, and another picked up and transferred to the car, in a similar manner.

To understand the advantages resulting from the use of this apparatus, it must be observed that when a blast is made, the great mass of rock falls immediately in front of the face, and very little of it is projected more than two or three yards. A movable section of track can therefore be laid to within fifteen or eighteen feet of the face, by turning over a few stones, if any are in the way. The long arm of the trussed beam will then reach entirely over the pile of stones, and place the drill stands just where they are required. The base of the stand occupying a space of only eight inches, and its distance from the face of the rock being less than two feet, the stones within this distance can be thrown back in a very few minutes, without waiting to load them upon cars. If any piece of rock is too large to be readily removed, it can be picked up by the trussed beam in the same

manner as the drill stands. As soon as a space of two feet from the face of the rock has been cleared, the stands can be placed, the pipes connected and the drilling resumed; and while this operation is progressing, cars can be brought forward, and the material removed before the next set of holes shall be prepared for blasting.

In this operation will be perceived a striking advantage in Haupt's drill over the Mount Cenis perforators, or any other in which the drilling tool is inserted in a socket at the forward end of the piston rod. Allowing only one foot for the projection of the piston rod when at the forward end of the stroke, and the length of the drilling tool not less than three feet, the front of the drill cylinder must be at least four feet from the face of the rock, and in some, seven or eight feet. This great projection of the drilling tool also requires that its forward end shall be supported when the hole is commenced. With such machines it is almost impossible to resume the drilling of a new set of holes, until the material from the former blast has all been carried out, and thus these two operations, which to secure rapid progress, should be carried on simultaneously, must be performed successively.

By dividing the frame as in the plan of working adopted by the State Commissioners at the Hoosac Tunnel, some advantage is gained, as one-half of the space can be cleared, the track laid, and the half carriage run forward to recommence drilling with a portion of the machines, before the balance of the space is cleared; but it is believed that no other plan that has ever been proposed, will permit the resumption of drilling operations after a blast, with as little loss of time, and as little manual labor as the use of the tubular stands and the trussed lever for handling them.

When the trussed lever is not in use, it is run off upon a side track, which also serves as a place of deposit for cars, to keep the main track clear.

The second condition which has been enumerated as essential to secure the most rapid progress in tunneling, is the possession of facilities for resuming drilling operations immediately after a blast.

In the consideration of this subject, it will be assumed that the heading or advanced gallery is of the same sectional area as that given to the Hoosac Tunnel, which is fifteen feet wide, and six feet high, and that the problem to be solved, is to determine the mode by which the most expeditious progress possible can be secured in a gallery of these dimensions.

One condition of rapid progress is satisfied in the use of the trussed lever for expeditiously erecting and removing the drills, and placing them in position before the loose material is carried out; but to make these facilities available, there must be,

1. A properly constructed car, on which to transport the drills.
2. A means of quickly removing the powder smoke.
3. A convenient means of attaching the pipes which convey the power, and preventing leakage of steam.
4. A means of supplying fresh air.
5. A supply of water for the holes.
6. Such a disposition of pipes, tracks and machinery, as not to interfere with operations, or be exposed to damage.

The car upon which the drill stands are removed, consists of a frame twelve feet long, supported on low wheels; on the top are several cross pieces four feet long. As the drill stands are six feet long and one foot and a half wide, the top of this car would afford ample room for four stands. The trussed lever takes hold of the back of the stand, and as it is turned on the swivel the face which was next to the rock is presented to the car, the front of the drill cylinder projects downwards, and the rear upwards. Thus they lie in perfect security, the columns only being in contact with the car.

The power used is supposed to be steam, and the manipulations described have reference to its use; but if compressed air should be employed, they would be very similar.

In the use of steam it is desirable that the joints should be tight, and the glands all accessible, so that they can be tightened if found to leak, also that the exhaust steam instead of being allowed to escape into the tunnel should be carried away by a separate pipe. A mode of forming the joints and of packing the glands will be described hereafter.

The car upon which the drill stands are transported, is connected by rigid couplings with the portable boiler, and carries in a secure position beneath the axles the steam pipe which supplies power to the drills.

The end of the steam pipe projects about a foot beyond the front end of the car where there is a globe valve, and the continuation of the pipe is by about ten feet of gum steam hose and terminated with ten feet of metallic pipe having upon it as many nozzles as it is proposed to use stands.

To each nozzle is attached two or three feet of inch and a quarter gum steam hose which connects the steam pipe with the base of each stand.

It will be observed that the only connections to be made in applying steam will be a single one at the base of each stand. The gum pipes belonging to each stand are not disconnected except when a cylinder is to be removed from a stand and another inserted. The short pieces of hose connected with the ten feet of metallic steam pipe which lies in front of the stands remain permanently attached thereto, and when the stands have been placed upon the car ready for removal, the piece of metallic pipe with its attachments is laid on top, the flexibility of the gum hose permitting this to be done without inconvenience.

The pipe to carry away the exhaust should be larger than the steam pipe, say five or six inches in diameter. This pipe is also ten feet long, lies in front of the stands beside the steam pipe and is furnished with the same number of nozzles and short pieces of hose. The exhaust pipe and hose may be light and thin, as the pressure is very slight.

The continuation of the exhaust pipe into the vacuum box to be hereafter described, should be by short pieces of gum pipe in lengths of ten or twelve feet, so as to admit of convenient extension as the work progresses without extending the vacuum box more frequently than in lengths of about sixteen feet.

This piece of exhaust pipe with its attachments is also to be removed with the stands preparatory to a blast and placed on the car.

The track upon which the car runs is a temporary one com-

posed of sections of two rails, each twelve feet long, connected by cross-rods. The rails are dowelled into each other at the ends; they are laid upon the bottom without cross-ties and leveled roughly with a few blocks or stones where support may be required.

As the car is run back, these sections which are very light and readily handled, are lifted and placed upon the car to the extent of about six sections, beyond which there is not much danger of breakage.

The rails may be of timber five inches square, with strap iron on top, dowels in the ends, and about four eye-bolts in the side. The connecting rods should be bent at right angles for a couple of inches at each end to pass through the eye-bolts. Thus all the pieces can be of exact dimensions and interchangeable; they will pack closely and can be laid down or taken up with great facility.

It has been stated that the car is attached permanently to the boiler or steam generator, and to this must be also attached a tender with fuel and water. Twelve drills would require a forty-horse power boiler, weighing about three thousand five hundred pounds, water in boiler one thousand five hundred pounds, water to run drills an hour two thousand two hundred pounds, drills and stands two thousand pounds, fuel for an hour five hundred pounds, car, tender, &c., three thousand pounds. Total weight to be moved, say seven tons.

The tractive force required to move an ordinary car on a straight and level rail road is eight pounds per ton, but owing to imperfections of track and small size of wheels, twenty pounds per ton will be allowed in this calculation.

Seven tons would therefore require a power of one hundred and forty pounds, or to overcome inertia, say two hundred pounds.

Three men should be able to push the train, but it is proposed to cast the large wheels of the boiler with teeth on the flanges, and use a pinion and crank to move them.

If the pinion should be six inches in diameter, and the handle of the crank be eighteen inches, the power exerted on the axle of the wheel, friction not considered, would be twelve times as

great as that applied to the crank, and allowing for friction twenty-five pounds on the crank should move the train.

The time required to remove the train to a safe distance is readily determined; the pinion being six inches in diameter, and the wheel thirty-six inches, six revolutions of the pinion would give one of the wheel, and as eighteen revolutions per minute would be a moderate speed of crank, this would give three revolutions of the wheel, or twenty-eight feet per minute. To remove the train to a distance of one hundred and fifty feet, would require about five minutes, and it would not be possible to get ready for blasting earlier than this with any improvement that can be introduced.

In returning to resume work, it is obvious that the train can be moved with the crank quite as fast as the rails can be laid and adjusted.

It is proper to observe that space in a tunnel is very limited in two directions, in height and width, but in length there is practically no limit. By the proposed plan of operations the space immediately behind the drills, where the pile of debris lies, is entirely unoccupied by any machinery or pipes, excepting a small portion of one corner where the vacuum box is placed. The boiler and tender, car and contents, take up only four feet, leaving eleven feet unoccupied, which would be amply sufficient for two tracks; but it must be observed that the track occupied by the boiler extends back say about three hundred feet, beyond which the whole tunnel is unoccupied by any machinery connected with the arrangements for mechanical drilling.

It cannot be doubted, therefore, that the proposed machinery and plan of operation afford facilities for quickly erecting and removing the perforators without interfering with the removal of material.

The means proposed for removing the powder smoke, are the same as those for ventilating the tunnel, and furnishing draft for the boiler, which will be more fully considered under the head of ventilation; it is sufficient to state here, that an air box is carried in the angle of the tunnel, to the very face of the rock; that it is protected as represented in the plate, by piling stones or

logs upon it, that a vacuum is produced in the pipe by suitable means on the outside of the tunnel; that the powder smoke and vitiated air are drawn into this pipe, and carried out without being allowed to poison the air of the whole tunnel, as is the case where air is forced in by compressors, and the smoke driven out at the end.

The means of applying the power are very simple. In the first attempts of the inventor to use steam in tunneling, the boiler was stationed about one hundred and fifty feet from the perforators and the steam carried for this distance in pipes. To accommodate the length of the pipe to the advancement of the work, the last joint was made with a smaller pipe sliding within a larger one, and a section of gum hose, or rather several pieces of smaller diameter connected the steam pipe with the drill stands. This arrangement was much more inconvenient than that which has been described, in which no extensions of steam pipes are necessary, but only a gradual advance of the steam generator on the track as the work progresses. This permits firm and permanent joints, except at the stands; and if one of these connecting joints should become detached, and permit the escape of steam, the men are in no danger, for they are behind, and by the system of ventilation adopted, the air moves towards the face of the work, and the escaping steam would be drawn into the vacuum box before it could escape into the tunnel to any considerable distance; besides the supply valve at the boiler would be immediately closed by the attendant, and the steam shut off.

As only two attachments are to be made to each stand to set the drills in motion, it becomes a matter of comparatively little consequence, what form of coupling is adopted, as but little time can be lost in making the connection. The case was very different when the steam and exhaust were carried one hundred and fifty feet in pipes, which had to be taken up and relaid at every blast. Still it is desirable that an operation that can be performed in a second, should not consume a minute; and a coupling which will be secure, and which can be attached and detached by simple pressure, without turning a screw, or using a spanner, is desirable.

The supply of water for the holes while drilling, does not require that a constant jet should be injected into each hole while being drilled. A supply at short intervals is sufficient. The report of the commissioners on the Hoosac Tunnel states, that the provision for injecting water into the drill holes was only partially availed of. Practically, the most simple and convenient mode of furnishing water for the drill holes, would be to carry a small tank upon the forward end of the car, where it would be very accessible, and inject the water by means of large syringes, one of which to each stand would be amply sufficient. Or if preferred, a close tank could be suspended below the axles, or along the middle of the car, connected with an air chamber into which air could be pumped by a hand pump attached to the car, so as to produce a pressure upon the surface, or still more simply a portion of steam could be admitted to the tank above the water, so as to produce a moderate pressure; the water could then be thrown into the holes by means of a hose. The water question is a very simple one, and presents no difficulty; it is, moreover, independent of the system of mechanical tunneling that may be adopted, and is as necessary for one as for another. The car however offers facilities for carrying the water which other systems might not as conveniently furnish.

POWER FOR OPERATING DRILLS.

Engineers who have heretofore attempted to solve the problem of determining a practicable mode of applying machinery to facilitate the operations of tunneling, have uniformly assumed that the creation of the power inside of the tunnel was impossible, and that it must necessarily be transmitted from some source of power on the outside, if machinery for drilling rock be used in any manner. In this consists a radical difference between the system proposed by General Haupt, and all others; he does not assume the impossibility of generating power in a mine or tunnel, but does generate and apply it just when and where it is required for use, and that too, as effectively, conveniently and simply as if the operations were conducted on the outside.

The first suggestion for transmitting power to drive machinery

in tunneling, appears to have been made by Chevalier Mauss, in his report on a plan for tunneling the Alps.

This engineer, who had successfully transmitted power to a distance of two miles, for the purpose of working inclined planes by means of straps supported on rollers, conceived the idea of using similar means in tunneling. His apparatus was designed to cut horizontal and vertical grooves in the face of the rock, and then break off the prismoidal blocks by means of wedges.

The plan of Chevalier Mauss was not practically tested, and subsequently that of Mr. Sommellier and his associates was adopted, in which compressed air is the motive power used.

Before committing the Governments of France and Sardinia to the great expenses required in the introduction of this system, elaborate experiments were made by a properly constituted commission, to determine its practicability.

Assuming that a machine could be invented, capable of drilling holes in rock by the agency of compressed air, it became necessary to determine,

1. The number of perforators that it would be desirable to operate at one time.

2. The quantity of air at the required tension necessary to operate them.

3. The additional quantity of air necessary for ventilation.

4. The amount and kind of power necessary to furnish the air at the proper tension, and the best mode of providing it.

5. The capacity of the reservoirs necessary to contain the compressed air, and maintain uniformity of tension while working.

6. The allowance to be made for loss of power by transmission through the pipes.

The number of perforators used at the Mount Cenis Tunnel is nine, and the average number of blows per minute is two hundred and seventy.

The Mount Cenis perforator consists of two cylinders; the larger being thirteen and one-half inches long, and the air acts on a ring at the back end of the piston, containing an area of four and four hundred and seventeen thousandths square inches, and at the forward end of two and sixty-five one-hundredths square inches.

The piston occupies a space of four inches in the length of the cylinder. If the piston traversed the whole length of the cylinder, the quantity of air consumed at each stroke would be one hundred and thirty-four cubic inches, but as the stroke is variable and as the area at the forward end of the piston is less than at the back end, the quantity actually consumed will be less, and probably the average will not exceed one hundred and ten cubic inches.

The valves are worked by an independent cylinder, which is three and a half inches long, two and one-quarter inches in diameter, and the piston of which occupies one inch. This cylinder requires therefore an additional amount of air at each stroke of twenty cubic inches, or allowing for clearances twenty-five inches.

The total average consumption of air at each stroke would therefore be about one hundred and thirty-five cubic inches.

Nine perforators making two hundred and seventy blows per minute would consume one hundred and ninety cubic feet of air per minute at a tension of five atmospheres, equivalent to nine hundred and fifty cubic feet per minute, at the ordinary tension.

The amount of air required for ventilation was estimated by assuming as the result of experiment and observation,

Ten cubic meters of air per hour as requisite to furnish ventilation for each man.

Seven cubic meters of air per hour to support combustion for each lamp.

Two hundred and fifty cubic meters of air per hour to dilute the gases generated by the explosion of one kilogramme of powder to an extent sufficient to permit them to be breathed.

The consumption of powder was estimated at twenty-four kilogrammes in twenty-four hours.

It was found that the quantity of air required for ordinary working at the atmospheric tension was two thousand one hundred and eighteen cubic feet per minute, to be increased after a blast.

The power required at both ends of the tunnel to work the hydraulic compressors was estimated to be six hundred and fifty horse power.

The apparatus required to compress air at the Mount Cenis Tunnel, consisted of cylinders into which the water was admitted at the bottom, under a sufficient head, forcing the air into a smaller space at the top; when the proper tension was attained, the air opened a valve and escaped into the reservoir.

As the horse power expended is measured by the space passed over under a given pressure, it is evident that if air is compressed by this system into one-fifth of its original bulk, the power expended in compressing it will pass over a space represented by four, while the air occupies a space represented by one. Therefore the power secured by the use of the compressed air cannot be more than one-fourth of the power expended in compressing it; to be reduced still further when friction and other resistances are considered.

Under other systems of compressing air, the loss may be reduced, but it will always be considerable. One of the most favorable, consists of several cylinders containing pistons worked from the same shaft, the cranks placed at different angles, and the uniformity of motion and resistance maintained by heavy fly-wheels.

Whatever may be the plan adopted for compressing air independently of the loss of power attendant upon this operation, there must be another serious loss in its transmission.

To obtain data by means of which to determine this loss a series of extremely valuable experiments were made at the Mount Cenis Tunnel, by a commission of gentlemen of eminent scientific attainments, appointed by government, consisting of Messrs. De Nérache, Giulio, Ménabréa, Rura and Sella.

After having satisfied themselves that the hydraulic air compressors could furnish a large quantity of air at high pressure, the commission undertook to determine carefully the diminution of tension, which, near the drilling machines, would result from the resistance of the sides of the pipes to the motion of the air. With this view, special experiments were instituted on a system composed of three hundred and one meters of metallic pipe, continued by ninety-eight meters of India-rubber hose. Mercurial gauges were used to ascertain the tension of the air simultaneously

at different points, and observations were also made on the time of passage and the velocity of the air which escaped. These data, compared with the diameter of the pipe, have shown the force of the elastic fluid at the commencement and at the end of the pipe, which has enabled them to trace accurately a curve for the interpretation of the results. In extending and comparing these calculations, the experimenters formed the following table, which gives the results of their observations:—

Loss of Tension for one thousand meters of pipe expressed in Millimeters of a Column of Mercury.

Velocity of air at the entrance of the pipe in meters per second.	Diameter of Pipes in the Clear expressed in decimals of a meter.					
	0.10.	*0.15.*	*0.20.*	*0.25.*	*0.30.*	*0.35.*
1,...........................	6	4	3	3	2	2
2,...........................	26	18	13	11	9	8
3,...........................	62	42	31	25	21	18
4,...........................	108	72	54	44	36	31
5,...........................	167	112	84	67	56	48
6,...........................	233	156	117	94	78	67

Two laws will be observed by an inspection of this table.

1. The loss of tension or resistance is inversely as the diameters of the pipes.

2. The loss of tension is directly as the squares of the velocities.

The quantity of air required per minute at the Mount Cenis Tunnel, was as previously stated, two thousand one hundred and eighteen cubic feet per hour, equivalent to 35.3 cubic feet per second at the ordinary tension.

If this air passed through a pipe eight inches in diameter, the velocity must be 101.6 feet per second in the pipe, or thirty-one meters per second at the ordinary tension, or condensed under a pressure of four atmospheres, the velocity must be eight meters per second.

It will be perceived from an inspection of the table, that the loss of tension is nearly in proportion as the square of the velo-

city; and as the supposed diameter, eight inches is nearly one-fifth of a meter, the fourth column should be used.

The loss of tension in one thousand meters, with a velocity per second of eight meters would be two hundred and sixteen millimeters of a column of mercury equal to eight and one-half inches, or more than one-fourth of an atmosphere.

If carried four miles, or six thousand four hundred and thirty-seven meters, the loss would be one and eight-tenths atmospheres, or twenty-seven pounds per square inch, reducing an effective pressure of sixty pounds at the reservoirs, to thirty-three pounds at the drills.

If by the system of hydraulic compressors, only one-fourth of the power expended in compressing air can be utilized in the air thus compressed at the reservoirs; and if an additional loss of nearly fifty per cent. is sustained in the transmission of the air to the middle of the Mount Cenis Tunnel, only one-eighth of the original power would remain as available for operating the perforators at that distance from the reservoirs, and in this calculation, friction and other ordinary resistances have not been considered.

A serious objection to the use of compressed air as a motive power in tunneling, arises therefore from the great loss of power in compression and transmission, from which, steam if applied directly and without transmission through long pipes, would be entirely exempt.

Another objection to compressed air, which is perhaps even more serious than the loss of power, arises from the defective ventilation, which will be considered in its proper place.

In consequence of the loss of tension which results from the transmission of air to long distances through pipes, it follows that when the advanced gallery at the Mount Cenis Tunnel approaches near the middle of the mountain, expedients must be used to compensate for this loss.

If the perforators require a pressure of sixty pounds to the square inch, they cannot be advantageously operated with thirty or thirty-five pounds, and therefore it will become necessary, either

To reduce the number of perforators in use, involving a reduction in the rate of progress, or increase the initial tension by an increase in the power at the reservoirs, or increase the number or diameters of the pipes which carry the air into the tunnel, and even then the defect of ventilation will not be removed.

Water may be used as a motive power, and could no doubt be applied advantageously in mining coal, and similar operations, by means of a water engine, the power being carried in pipes, and the connections made with India-rubber hose; but the movements of such engines must be slow; the number of blows in a given time, much less than can be attained with some form of pneumatic power, and the resistance in the transmission of the power much greater. The problem of the application of water to tunneling, will not therefore be discussed at this time.

It remains to consider the application of steam as a motive power in tunneling.

Why steam should have been so generally rejected by engineers as inapplicable, it is difficult to understand; probably because opinions were formed hastily, without reflection or investigation; for a very slight amount of either would have satisfied any intelligent mind that the apparent difficulties are far from insuperable.

What are the difficulties in the way of the direct application of steam as a motive power in tunneling, and what are the conditions of success?

1. If steam is generated outside a tunnel, it cannot be carried for any considerable distance without great losses by condensation.

Very true, and the remedy is, not to generate the steam outside, and not to carry it in pipes more than twenty or thirty feet.

2. If generated inside, we encounter,

The inconvenience of a boiler in the tunnel, with the occupation of space required for other purposes.

The necessity of carrying fuel and water into the tunnel.

The difficulty, usually considered an impossibility, of creating a draft for the boiler.

The escape of smoke and gases generated by combustion.

The escape of steam into the tunnel.

The heat of the boiler, pipes and escaped steam rendering it impracticable for the men to work.

The damage to such bulky machinery from blasts.

The difficulty of removing such machinery to a safe distance.

The danger of explosions.

Can any other objections be thought of? If not, we will proceed to show either that there is not the slightest force in any that have been stated, or that the remedy is simple and inexpensive.

The key to the solution of this important problem of the direct application of steam to tunneling, is found in one of those fortunate inventions or applications, of which the history of the steam engine exhibits numerous illustrations. It consists simply in the combination of a steam generator with a vacuum pipe, a combination patented by General Haupt, and which fulfils every condition required in the economical and convenient generation and application of steam, and at the same time secures a ventilation incomparably more perfect than compressed air, or any other system can furnish, even at an expenditure in construction and maintenance of machinery many times greater.

To proceed to the consideration of the objections which have been enumerated.

1. The space occupied by the boiler.

Space is limited in a tunnel only in two directions, height and breadth. In considering the subject, the ordinary dimensions of a tunnel heading in America will be taken, say, six feet high, and fifteen feet wide. No difficulty can exist in conforming to these dimensions elsewhere.

The boiler used by Mr. Haupt in his experiments at the Franklin Tunnel, was of locomotive form, three feet wide, five feet high from track, ten feet long, and was estimated at fifty-eight horse power.

The power required for nine drills, at three horse power each, was twenty-seven horse power, and the boiler was therefore double the capacity that was actually necessary; but an excess of power is no disadvantage.

The gauge of the track being forty inches, the extreme width of boiler outside of wheels was four feet, leaving eleven feet in the width of the tunnel unincumbered.

As the tracks are supposed to be of the usual gauge adopted in the mines of Pennsylvania, forty inches, and as the frames of the stone cars do not project beyond the wheels, the extreme width would be forty-four inches, and two tracks would occupy with cars, seven feet four inches, leaving three feet eight inches clearance to make up the eleven feet.

It appears therefore that even opposite the boiler there would be abundance of room for two tracks to carry away material, when in fact only one track at this point would be required. A siding to hold and shift cars would be placed behind the boiler where the whole width of the tunnel could be made available. (Plate 3.)

The space occupied by the boiler, therefore causes no inconvenience.

The next objection is the inconvenience of carrying fuel and water into the tunnel.

Water must be used in any system, and the inconvenience in one is not greater than in another; a pipe must be carried into the tunnel and extended from time to time as the work progresses. When the boiler is run back for the purpose of blasting, the tank attached thereto can always be filled without inconvenience or delay.

The stone cars which carry out material always return empty; and even if the quantity of fuel required should be increased fourfold, no expense or inconvenience could result from its transportation.

We will ascertain what amount of fuel can be consumed in twenty-four hours.

Nine drills should finish nine holes in twenty minutes. If twenty-seven holes be blasted at once, and eight blasts be discharged in twenty-four hours, the time actually occupied in drilling will be eight hours. The quantity of water evaporated when nine drills are at work will be twenty-seven cubic feet of water per hour, in eight hours two hundred and sixteen cubic feet re-

quiring one ton of coal or two cords of wood. Certainly not a very serious item either in cost or transportation.

The next objection to be considered, is the difficulty of creating a draft in the boilers without chimney or any of the ordinary means of accomplishing this object.

The provision made for draft consists of a vacuum box or pipe leading from the outside of the tunnel. The proper dimensions of this pipe will be considered under the head of ventilation, but it is sufficient to state here that a very moderate amount of power applied to a vacuum fan outside of the tunnel, will draw the air from the tunnel through the pipe with a velocity so great that if the smoke pipe of the boiler is connected with it, and the current passed entirely through the fire-box and flues, the draft becomes too great, and must be checked by dampers; at the same time all the smoke, gases, &c., are drawn into the vacuum box and carried out, and another anticipated difficulty is thus disposed of.

The next objection is the escape of steam into the tunnel. We ask why should it escape, and where does it escape from?

There is no escape at the boiler except when the pressure becomes so great as to raise the safety valve; a small pipe on the safety valve would instantly convey this steam into the vacuum pipe, but if the amount were tenfold greater, it would condense immediately without inconvenience to the workmen.

Steam cannot escape from the pipe, for no loose joints are required, except where the pipe is connected with the bottom of the stand, and as there is but one joint to be attended to there should be no excuse for any leakage at this point.

The stuffing boxes of the cylinders and steam chests present greater difficulties, but these are overcome by a mode of packing invented by Mr. Haupt, and illustrated in Plate 4.

The exhaust steam, it is scarcely necessary to say, does not escape into the tunnel; it is carried by a pipe of four or six inches diameter into the vacuum box, and as the pressure is very slight, this pipe need not be very stout; three-ply gum hose possesses ample strength.

The exhaust steam escaping in puffs into the vacuum box per-

forms a very important office in greatly assisting the ventilation at the extreme end of the heading where it is most needed.

Experience in the Franklin Tunnel has proved that a moderate leakage of steam from the pipes or stuffing boxes is not attended with any inconvenience. In the damp cold atmosphere of a tunnel it condenses quickly, but there is no excuse for leakage; it proves defective workmanship, or careless packing of the stuffing boxes.

The next objection, of inconvenience from the heat radiated from the boiler is purely imaginary; the very opposite was found to be the fact; the men would get near the boiler when not at work because the warmth was pleasant. If inconvenience were actually experienced, a jacket of felt would prove an effectual remedy.

The damage to the machinery from blasts is no greater with steam than with compressed air, but a barrier is always provided. This barrier, when a tunnel is driven by hand consists of a pile of stones. Sometimes a barricade of logs is used, sometimes doors faced with logs or boiler-plate iron. A convenient plan of barrier is represented in Plate 3, Fig. 5; which consists in frames three or four feet wide, and seven feet long, placed in the bottom of the tunnel where they are not in the way of anything. When a blast is to be made, they are tilted and propped. In blasting in a tunnel only the smaller stones are projected far enough to strike the barrier which is not required to be excessively heavy. The frames could be raised by two men, but the operation would be facilitated by the use of a lever of the form represented in Fig. 5.

The difficulty of removing the machinery, very slight under any circumstances, is entirely overcome by the use of the crank. One man can retire the train after drilling, before it would be possible to prepare for a blast.

The last objection is the danger of boiler explosions, but why should this danger be greater in a tunnel than in a work-shop or factory? The boiler can be made so strong that an explosion under a pressure of sixty pounds per square inch would be simply impossible if even the most ordinary intelligence were exercised in its

management. A boiler three feet in diameter, composed of boiler plates three-eighths of an inch thick, would be required to sustain a tensile strain of only one thousand six hundred and twenty pounds per square inch, from a pressure of sixty pounds per square inch in the boiler; this strain is less than one-thirtieth of that which would cause rupture.

We would appeal to engineers and practical men in view of the facts presented, and ask them is there any valid objection to the use of steam in tunneling? and if not, is it possible to secure any other power as simple, as efficacious, and as economical?

Of course we refer to such an application of steam to tunneling, as would exhibit at least ordinary judgment and intelligence. Not such an experiment as was once made at the Hoosac Tunnel, by lowering an awkwardly contrived steam drill into a shaft sending down steam from the top, letting the steam escape into the shaft, and attempting to handle the machine without providing any apparatus therefor. Of course the men burned their fingers, the escape steam drove them out of the shaft, and they, with the engineer in charge, voted steam a humbug.

VENTILATION.

The three indispensable requisites to the successful application of machinery to tunneling, are,

1. A machine adapted to drilling the holes.
2. A power applicable to driving the machinery.
3. An abundant supply of air.

A failure in either of these essentials would render the others valueless.

There are but two modes of supplying air in tunneling; one by forcing fresh air into the tunnel through pipes, and driving out the vitiated air at the mouth of the tunnel.

The other mode consists in drawing out the vitiated air through pipes, and allowing the fresh air to enter and replace the vacuum.

These modes of ventilation will be considered with reference to the power required to supply a given amount of air, and the efficiency of the ventilation which is thus secured.

The usual mode of ventilation consists in forcing fresh air into

the tunnel through pipes. This is the mode which has been adopted at the Mount Cenis Tunnel, and imitated by the State Commissioners of Massachusetts, at the Hoosac.

The compressed air at the Mount Cenis Tunnel is used for the double purpose of furnishing power for the drills, and by its escape aiding in ventilation.

The power required with the plan of compressors used at Mount Cenis, is several hundred horse power.

The ventilation secured in this way, is represented as being exceedingly defective, excepting at the extreme end, where the perforators are at work. A cloudy, smoky, vitiated atmosphere extends from a short distance back of the machinery all the way to the entrance. The men engaged at the enlargement must breathe this poisoned air containing the deleterious gases from the powder smoke, and the carbonic acid from the lamps and lungs of the miners. In view of these facts, the statement of the press that great mortality sometimes prevails amongst the workmen is not improbable.

By the vacuum plan of ventilation, the powder smoke and vitiated air are drawn into a pipe, and carried out of the tunnel, while a constant current of pure fresh air flows in at the end, and continues to the face of the work, leaving the atmosphere clear, the lights brilliant, and permitting the instrumental observations of the engineers in giving marks for grade and alignment, without suspending blasting or any other operation.

The power required to furnish a given quantity of fresh air on the vacuum plan, was investigated theoretically and experimentally by Mr. Haupt, at the Franklin Tunnel, in the fall of 1865.

One important result of this investigation was, that the power required to draw a given quantity of air through a short pipe, was inversely, as the square of the area or fourth power of the diameter; in other words, if the diameter should be doubled, the power required would be reduced to one-sixteenth, and therefore in practice, the largest possible area should be given to the air passage.

These theoretical investigations furnished no information in

regard to the power expended in overcoming the resistance due to friction in the pipes, and it became necessary to make a practical test to determine data for calculations.

For this purpose, a wooden box was constructed of rough boards. The size of the box or pipe was one hundred and ten square inches, inside area; length, one thousand two hundred and fifty seven feet.

The pipe was connected with a fan outside the tunnel, driven by a small engine of ten horse power.

The vacuum fan was four feet in diameter, and the number of revolutions varied in the experiments from eight hundred and eighty to twelve hundred and twenty.

The velocity of the air through the pipe was determined by exploding cartridges at regular intervals in the pipe by electricity, and counting the oscillations of a pendulum, regulated to make one hundred per minute from the instant when the key was touched to explode the cartridge, until the smoke appeared at the fan. In this way also the leakage through cracks in the box was ascertained.

The pressure of air in the pipe was determined by an anemometer.

The vane of the anemometer presented a surface of six and one-quarter square inches; it was inserted at any desired point, by making a saw slit in the box; one ounce pressure on the vane, represented 1.4335 pounds on a square foot of surface.

A pressure of air of .005 pounds per square foot is due to a velocity of eighty-eight feet per second.

A pressure of .020 pounds per square foot, to a velocity of one hundred and seventy-six feet per second.

In general, if the velocities are represented by

$$v, \ 2\,v, \ 3\,v, \ 4\,v, \ n\,v,$$

The pressure will be

$$p, \ 4\,p, \ 9\,p, \ 16\,p, \ n^2 p,$$

or the pressures are as the squares of the velocities.

The velocity due to a pressure of one ounce on the vane of the anemometer was found to be one thousand four hundred and ninety-one feet per minute, and to obtain the velocity due to any

other pressure, it was only necessary to multiply the square root of the observed pressure in ounces, by the constant number, one thousand four hundred and ninety-one.

Experiments were continued for several days, and the results tabulated; but although interesting to scientific minds, the practical conclusions are all that will be here stated.

When the fly wheel of the engine made forty-five revolutions and the fan eight hundred and eighty-four per minute, the length of pipe being one thousand and seventy-eight feet, and area one hundred and ten square inches, the velocity of the air in the pipe was two thousand seven hundred and forty-three feet per minute, and the discharge two thousand and ninety-six cubic feet; but when the length of pipe was reduced to one hundred and sixteen feet, the velocity was increased to four thousand four hundred and seventy-three feet per minute, and the discharge to three thousand four hundred and thirteen cubic feet. The difference of one thousand three hundred and seventeen cubic feet per minute, was a loss due to the additional nine hundred and seventy-eight feet of pipe through which the air was drawn.

But this retardation would have been increased, if the air box had been perfectly tight, for the air entering through leakages, would travel a shorter distance in the box, and consequently experience less frictional resistance than that which entered at the ends.

Had the box been perfectly tight, the quantity of air passing at all points would have been the same, but in experiment No. 2, at a distance of one hundred feet from the fan, two thousand and ninety-six cubic feet of air passed per minute, while at the end of the pipe only one thousand five hundred and twenty-eight cubic feet entered. The difference five hundred and sixty-eight cubic feet, or nearly twenty-five per cent. was the amount of leakage.

Had the box been perfectly tight, it cannot be assumed that the whole of this amount of five hundred and sixty-eight cubic feet would have entered at the end, for the friction would have reduced it. If the leakage and resistance be assumed, as in proportion to the length, which cannot vary greatly, from the fact, then, if the box had been tight, the quantity of air entering at the end

would have been one thousand eight hundred and twelve cubic feet per minute.

Now if three thousand four hundred and thirteen cubic feet of air per minute pass through a pipe one hundred and sixteen feet long, and with the same power one thousand eight hundred and twelve cubic feet pass through a pipe one thousand and seventy-eight feet long, then the loss by friction in the nine hundred and seventy-eight feet of pipe would be one thousand six hundred and one cubic feet, or one hundred and sixty-three cubic feet per hundred feet.

The distance from the opening at one hundred and sixteen feet from the fan to the discharge orifice including periphery of fan was one hundred and sixty feet, and the resistance due to this distance would reduce the cubic quantity of air discharged two hundred and sixty-one feet.

With a free discharge encountering no resistance from pipes, the volume of air per minute as deduced from these experiments would be three thousand six hundred and seventy-four cubic feet.

This discharge is due to a velocity of fan of eight hundred and eighty revolutions per minute; with one thousand two hundred revolutions per minute, the discharge should be increased to five thousand cubic feet.

In the theoretical discussion of the pressure fan by Bourne, the discharge of a fan of the same size very nearly, and making one thousand two hundred revolutions per minute, is given at five thousand one hundred and sixty cubic feet per minute.

This is quite a close agreement between theory and experiment, and it may be concluded from the experiments of Mr. Haupt, that a fan four feet in diameter and making eight hundred and eighty revolutions per minute, would discharge three thousand six hundred and seventy-four cubic feet of air per minute if not connected with pipes.

That when attached to a pipe or box of one hundred and ten square inches in cross section, the discharge is reduced to one thousand eight hundred and twenty cubic feet, or one-half, when the length of the pipe is one thousand one hundred and thirty-

eight feet, the fan acting to create a vacuum in the pipe, and the air propelled by atmospheric pressure.

Although the experiments were interrupted by the suspension of the work at the Franklin Tunnel, yet it would seem that certain laws may be considered as at least approximately established which govern the motion of air in pipes when produced by creating a partial vacuum at one end, and allowing the atmosphere to act freely at the other.

1. The friction in the pipe being left out of consideration, the power requisite to draw a given quantity of air through a pipe of given length will be inversely as the fourth power of the diameter, or inversely as the square of the area.

2. The quantity of air being constant, the power will be as the square of the velocity.

3. The velocity and power being constant, the quantity will be directly as the area.

4. Power and quantity remaining constant, area must increase according to some function of the distance.

The first three of these laws which are independent of friction are modified by those which follow.

5. The velocity, area and quantity being constant, the frictional resistance will be directly as the length of pipe, and the increment of power required to overcome it will be in the same proportion.

6. The experiments at the Mount Cenis Tunnel establish a sixth law, which is this, the loss of tension or resistance is inversely as the diameter. Now as the number of particles in contact with the surface as compared with the whole volume is reduced in proportion as the circumference is increased, this explains the cause of a reduced resistance with an increased frictional surface.

It would follow that quantity and velocity remaining constant, the resistance should be directly as the perimeter.

REMARKS.

The discharge being reduced to one-half, when the vacuum pipe has an area of one hundred and ten square inches, and length of one thousand one hundred and thirty-eight feet. To make

the discharge equal to the original quantity, the velocity must be doubled, and 'the power which is as the square of the velocity quadrupled.

As the quantity is reduced to one-half, at a distance of one thousand one hundred and thirty-eight feet, three-fourths of the power is required to overcome the resistance of the pipe.

If p represents the power exerted at the fan, $l =$ distance at which three-fourths of the power is expended in overcoming friction of pipe $=$ one thousand one hundred and thirty-eight feet.

A. $=$ Area of pipe $=$ one hundred and ten square inches.

Q. $=$ Quantity of air discharged per minute by fan without pipe.

The quantity remaining constant, the power required at the distance l, will be 4 p, at $2\,l = 7\,p$, at $3\,l = 10\,p$, at $n\,l = (3\,n+1)\,p$. But if it is desired that the power shall remain constant, and that the resistances from increased distance shall be compensated by an enlargement of area.

We then have these considerations to lead to the required area. (A′)

The quantity being supposed constant, an enlarged area reduces velocity in proportion to enlargement.

The reduction of velocity affects power, which is as the square of the velocity.

When the power is increased from p, to $(3\,n+1)$ p, the power being as the square of the velocities, and the velocities inversely as the areas, the power must be inversely as the square of the areas.

Therefore $(3\,n+1)\,p : 1\,p :: (\frac{1}{A})^2 : (\frac{1}{A'})^2$

from which it appears that $A' = A\sqrt{3\,n+1}$.

For example if $n = 5$, then the power required with the area A would be 16 p, or sixteen times the power at the fan, but if the area be increased so as to become $A\sqrt{3\,n+1} = 4\,A$, the power remains unchanged $= p$.

To make a practical application of the important results which this investigation has developed, let us assume a case applicable to the Mount Cenis Tunnel, in which the air for ventilation is to be carried a distance of four miles.

Let the vacuum box be constructed by flooring over the bottom

of a gallery, giving, say, ten square feet of sectional area, and let the question presented be, to determine the power which applied to one or more vacuum fans outside of the tunnel would exhaust two thousand one hundred and eighteen cubic feet of air per minute, from the extreme end of the gallery.

It will be remembered that two thousand one hundred and eighteen cubic feet per minute, was the estimated quantity required at the Mount Cenis Tunnel, which does not appear from published statements of observers to be actually furnished, although more than three hundred horse power are expended in compressing the air.

4 miles equals 21,120 feet, and $\frac{21120}{1188}=18$ nearly. The power at the end of the tunnel being $p=10$, $n=18$, $(3\ n+1)\ p=550$, or 550 horse power would draw 3674 cubic feet of air per minute, through a pipe with an area of 110 square inches, or .76 of a square foot, and of this, 540 horse power would be expended in overcoming the friction of the pipe.

If the area is enlarged, the velocity being reduced in proportion to the area, and the power and resistance being as the square of the velocity, they will also be diminished in proportion to the square of the area.

The area being enlarged in proportion as $\frac{76}{100}$: 10, or as 1 : 13, the velocity would be reduced in the same proportion; and if the resistances are as the squares of the velocity, the power to overcome them would be in the same proportion, and would be reduced from 540 horse power to $\frac{540\times 1}{13^2}=3\ \frac{2}{10}$.

But the quantity of air discharged is to be reduced from thirty-six hundred and seventy-four cubic feet per minute, to twenty-one hundred and twenty. As the velocities must be reduced in the same proportion, and as the power is as the square of the velocity, the power would be reduced as $3674^2 : 2120^2$, or about sixty-six per cent. less than the power necessary to pass thirty-six hundred and seventy-four cubic feet.

The perimeter of the section in proportion to area must also be considered. An area of ten square feet in the form of a rectangle ten by one, has a perimeter of twenty-two lineal feet: in the form

of a square the perimeter with the same area would be twelve and a half feet, and in the form of a circle eleven and a quarter feet, so that in the rectangular box, according to rule six, page fifty-two, double the power would be required as compared with a circular area.

After making every allowance, it would appear that with a pipe or box of ten square feet sectional area, and an application of ten horse power, more than six thousand cubic feet of air per minute should be furnished, which is three times as much as the hydraulic compressors could deliver with an expenditure of three hundred horse power.

Compressed air must move under high tension, at great velocity and encounter great resistances; the pipes must be very strong, of very small areas comparatively and very expensive.

The vacuum plan carries the air at very feeble tension, with very low velocity, with slight resistance, in pipes of rough boards, of large area, and furnished at small expense.

To pass twenty-one hundred cubic feet of air per minute, through a pipe of eight inches diameter, requires a velocity of over twelve hundred feet per minute, even after compression to one-fifth of its bulk, with corresponding increase in frictional resistance.

The vacuum plan will pass the same quantity of air *without compression*, through a passage of ten square feet at a velocity of only two hundred feet per minute.

It must be observed in the practical consideration of this question of ventilation, that the theoretical results cannot be fully realized, that allowance must be made for the leakage of pipes, for the increased resistances from the rough rocky surfaces over which the air is drawn at the bottom of the tunnel, for the reduced area of the pipe which is extended for about one hundred and fifty feet to the face of the heading, and for the resistances in drawing air through the grate flues and smoke-pipe of the boiler, but after making ample allowances for all these increased resistances, it must be obvious that the power required to supply a given amount of air is very much less on the vacuum plan than on that of compressed air, and that the ventilation secured is incompa-

rably more perfect. It must be observed also that the number of fans can be increased to any desired extent at trifling cost.

We think that we have demonstrated the propositions which we attempted to establish, that a perforator has been provided so perfect as apparently not to admit of improvement, a power entirely controllable, and adapted to its uses, and a perfect system of ventilation. These great results, the fruits of the labors and expenditures of the inventor for ten years, must, when known and appreciated, revolutionize mining and tunneling operations throughout the world.

Mountain chains will cease to bar the progress of improvements when the work of a generation in perforating them can be compressed into a brief period of five years, with reduced cost at the same time.

COST OF THE SYSTEM.

For a tunnel heading fifteen feet wide, six feet high, working nine drills at a time on the face, there should be provided—

27	Perforators ($\frac{2}{3}$ in reserve), $500	$13,500
3	Stands, $200	600
1	Trussed Beam, $400	400
1	Thirty horse boiler	1500
	Car and Tender	1000
	Dirt Cars	500
	Engine and Fan outside, twenty horse	2500
	Machinery for Repair Shop	5000
	Smith Shop	500
	Buildings	5000
	Boards for Air Boxes	500
	Water and Steam Pipes, etc	500
		$31,500

At the tunnel of the Alps, the outside expenditures in machinery, buildings, power, etc., amounted to one million of dollars for both ends.

At the Hoosac Tunnel the expenditures for similar purposes exceeded seven hundred thousand dollars, chiefly for one end

The plan of General Haupt, therefore, compares with others even more favorably in economy than in efficiency.

MINING TUNNEL.

To drive a Mining Tunnel, or adit with a section six feet square, only two perforators need be used at one time, consuming six horse power of steam. The boiler may be two feet wide and four feet high. The air box four feet wide. The trussed beam for handling the drill stand can be smaller than before described. Everything should be on a reduced scale, but the same general principles should be observed, taking care to provide a surplus of power outside, as the difference between an engine that is just sufficient, and a larger one is very small.

ESTIMATE FOR THE EQUIPMENT OF A MINING TUNNEL.

6	Drills, $500	$3000
1	Stand, $200	200
1	Trussed Beam	250
1	Eight horse power Boiler	600
	Car and Tender	400
	Dirt Cars	150
	Outside Engine and Fan	1000
	Small Lathe and other tools for shop	1000
	Smith Shop, tools, etc	200
	Buildings	500
	Boards	200
	Water and Steam Pipes	100
		$7600

Of this equipment it must be observed that very little will be actually used up upon the works; nearly all of it can be carried away when the work is completed, and used again. This is not the case with water power.

ESTIMATED PROGRESS.

Nine drills are supposed to be set at work in a heading fifteen feet wide by six feet high, and to drill three sets of holes before removed.

Suppose a blast has been made. The barriers are immediately lowered, requiring two minutes, tracks laid in five minutes, first drill stand picked up and run forward in five minutes. In the

meantime the smoke has all been cleared by being drawn into the vacuum box, and a space of one square foot at least cleared for the bottom of the first drill stand. The stand is then set in its place, and the men who attend to it proceed to adjust it, and place the drills in position while the trussed beam is used to pick up and place Nos. 2 and 3 in the same manner.

In fifteen minutes from the time of a blast, stand No. 1 can be at work, even allowing ten minutes to move forward the boiler and make the one connection which is all that is required to admit steam, and one for the exhaust.

In any ordinary rock, the rate of drilling will not be less than two inches per minute, but allow twenty minutes to drill a hole twenty-six inches deep, and ten minutes to shift the stand after one set of holes has been drilled, the three sets of holes and the intervals will consume one hour and twenty minutes; add the fifteen minutes which elapse before the first set of drills commence work, and fifteen minutes more between the removal of the first and last stands, and the time thus far amounts to one hour and fifty minutes.

There remains the loading and blasting of the holes.

The holes should be loaded as fast as drilled, so that when the last three holes are finished, all the rest are ready for blasting; five minutes should finish the loading, and at the end of ten minutes the electric messenger can be sent to do its work of simultaneous explosion. In the meantime the boiler has been run back, the barrier raised, the debris from former blast removed and all ready for the next explosion.

With such thorough drill as is exhibited in the exercises of an artillery battery, there seems to be no difficulty in blasting once in two hours, or at least ten times in twenty-four hours; and the progress could not be less than ten lineal feet per day. The average progress in the Hoosac Tunnel was one foot for each twenty holes drilled by hand with separate explosions. Twenty-seven holes fired at once should produce a far greater effect, not considering the advantage to be derived from the use of more powerful explosives than blasting powder, and ten simultaneous blasts per day, should give a progress of not less than

twelve feet; working from two faces the 1800 feet intervening between the workings at the east end and of the west shaft at the Hoosac Tunnel should be finished in seven hundred and fifty days, which is sooner than the central shaft worked by hand labor can be carried down to grade.

ESTIMATE OF COST.

Twenty-seven holes blasted ten times in twenty-four hours, each hole consuming half-a-pound of powder would give

One hundred and thirty-five pounds of powder at 20 cts. per lb.		$27.00
One thousand feet of fuse or its equivalent		18.00
Steel same as powder		27.00
Light		4.00
Fuel, one ton coal		10-00
Two engineers outside $3.00	$ 6	
Six machinists $3.00	18	
Four blacksmiths $2.50	10	
Twelve machinists at drills $3.00	36	
Two firemen in tunnel $2.00	4	
Eight to remove material $1.75	14	
Four car-men and drivers $1.75	7	
Eight extra $1.75	14	
Forty-six Total labor		110.00
		$196.00

A progress of twelve feet would cost, $16.33 per lineal foot, or $5.40 per cubic yard, which is about one half the cost by hand labor with four times the progress per day.

SPACE OCCUPIED BY GASES GENERATED IN EXPLOSIONS.

Twenty-seven holes blasted simultaneously, each containing $\frac{6}{10}$ of a pound of powder occupying eighteen cubic inches of space, expanding two thousand times its original volume would give

$$\frac{27 \times 18 \times 2000}{1728} = 562 \text{ cubic feet.}$$

$$\frac{562}{90} = 6.2 \text{ lineal feet, as the space occupied in the tunnel.}$$

If the exhaustion of air at the extreme end is at the rate of even one thousand two hundred cubic feet per minute, the smoke would all be removed in half a minute.

AIR REQUIRED FOR TUNNELING.

In the use of Haupt's system by steam, the air required may be determined by the following data.

Sixteen pounds of air are required for the combustion of one pound of coal.

One cubic foot of water is evaporated by ten pounds coal, and represents one horse power.

One pound of air weighs .075 pound avoirdupois; one horse power consumes one hundred and sixty pounds of air, or two thousand one hundred and thirty-three cubic feet per hour.

At the Mount Cenis Tunnel it was ascertained that ten cubic meters of air per hour were required for the respiration of one man.

Seven cubic meters per hour to support the combustion of one lamp.

Two hundred and fifty cubic meters of air are required to dilute the gases generated by the explosion of one kilogramme of powder to an extent sufficient to permit them to be taken into the lungs, all of which it must be observed is saved by the adoption of the vacuum plan of ventilation, as this pernicious air is not breathed by the workmen.

The quantity of air required will be determined at the period of maximum consumption when the greatest number of men are in the tunnel and the machines all at work.

Nine machines consuming each three horse-power of steam require a thirty horse-power boiler, consuming three hundred pounds of coal per hour, and sixty-four thousand cubic feet of air per hour, or one thousand and sixty-six cubic feet per minute.

Twenty-three men in tunnel, each three hundred and fifty-three cubic feet per hour, or six cubic feet per minute........................	138
Twelve lamps each two hundred and forty-seven cubic feet per hour, or 4.6 per minute..	55
Air required per minute.	1259 cu. ft.

To furnish this amount of air by a vacuum fan at a distance of two miles through a pipe or box of ten square feet sectional area, would not require five-horse power.

IMPROVED MEANS OF FURNISHING LIGHT.

The attention of Mr. Haupt has not been confined to the consideration of the primary essentials in tunneling. He has experimented to some extent on other means of facilitating progress by securing improved means of lighting and blasting, some of which will be briefly alluded to.

To dispense with the smoke of lamps or candles, and secure a brilliant light, a large magneto-electrical machine was constructed under the direction of Mr. George W. Beardslee. This machine was no doubt the largest of the kind ever constructed; its weight was three tons, and cost over three thousand dollars. It was intended to drive it by means of the engine outside the tunnel, and convey the current by wires, the light being produced by a coil of platinum wire in the focus of a parabolic mirror. Although a brilliant light was obtained by means of this machine when the reflector was within one hundred feet, yet it was found impossible to carry the current to any great distance from the machine, and therefore it was not used in the tunnel. The present plan of operations in which the boiler is movable, would permit such a machine to be attached to the rear end of the tender, and rotated by a small steam cylinder. This would obviate the necessity of carrying the current any considerable distance from the generating machine.

Improvements have recently been made in the production of electrical light, and there is but little doubt that it can be made practically available in tunneling.

ALIGNMENT.

The same apparatus which produced the light was intended to be used in maintaining the grade and alignment, by projecting on the face of the rock from the reflector, the shadow of a cross, from which both the vertical and horizontal measurements could be made, a mark always before the eyes of the workmen, and which blasts could not efface.

BLASTING.

Another use to be made of the electrical apparatus was in securing simultaneous discharges from a large number of holes.

Experiments were made with a smaller machine, constructed by Mr. Beardslee. It was found that a cartridge could be exploded at a distance of one hundred miles, using the ordinary telegraph wires. Also, that fifty cartridges attached to a wire outside the tunnel, would all explode, but inside the tunnel not more than six or seven of the holes would be exploded. The cause of this was ascertained, and Mr. Haupt was occupied with plans to provide a remedy, when the suspension of operations at the Franklin Tunnel put a stop to the experiments, and no opportunity of renewing them has since been presented.

The last report of the State Commissioners on the Hoosac Tunnel, shows that efforts in the same direction have been made by them, that their engineers, assisted by Colonel Schaffner, could not explode more than about five charges at once, but that Mr. J. J. Levy, of London, who is connected with gun cotton works, made certain suggestions, in consequence of which, certain new machines and fuses were procured, by the use of which so many as thirty-one charges have been fired at once.

If this machine is not exactly what it should be, no doubt can be entertained that the difficulties will be overcome, so soon as the attention of electricians shall be more generally directed to the subject.

In the meantime a very close approximation to simultaneity can be secured, by the use of fuses, as the Gomez fuse, several yards of which will explode in a fraction of a second. By making these fuses of exactly equal lengths, and bringing the ends together, they may all be ignited from a single electrical cartridge. The cost of the fuse is, however, considerable, and further experiments are necessary to determine what is the very best practical plan for securing simultaneous explosions.

LOADING HOLES.

The old way of pouring in loose powder and tamping with stones, will not answer in expeditious tunneling. The only proper mode of loading holes is to have the powder enclosed in previously prepared cartridges, in which the fuses or electrical wires are inserted. These cartridges were prepared by Mr. Haupt in

the following manner: A stiff case was made by pasting brown paper, and rolling it around a stick, so as to give a diameter of one and a half inches; a paper wad dipped in paste, forms the bottom; when dry, the powder was introduced, with the fuse or wires, then a wad, then dry sand, until the whole length was about twenty inches. In loading, a cartridge was pushed into a hole, followed by a pointed wooden plug, tightly driven. The point of the plug would break the cartridge and spread the sand. Lastly, an ordinary rail road spike was driven into the end of the plug, which split it into four quarters, driving the pieces firmly against the sides of the hole. This mode of tamping was found to answer perfectly, and was so expeditious that several holes could be loaded in a minute.

NITRO-GLYCERINE.

The report of the Hoosac Tunnel Commissioners states that the experiments with Nitro-Glycerine have been very successful; that no accident has resulted from it; that there seems to be little risk if the article is good, and ordinary care taken in its use, and that double progress can be made with glycerine over that made with powder, at less cost. The report states that "whenever its extensive use shall be concluded upon, it will be necessary to secure the services of some scientific person expert in handling it, that some *antidote against headache* may be discovered, and that the use may be reduced to the lowest possible point.

The antidote against headache caused by breathing the noxious gases resulting from the explosion of glycerine, will occur to the reader at once. It consists simply in adopting the vacuum plan of ventilation, which would carry off any vapors or gases without injury to the workmen, even if they were as poisonous as the fumes of prussic acid.

ILLUSTRATIONS ON PLATE 4.

Fig. 1 Illustrates the mode of blasting, which was found to be very expeditious. The powder is enclosed in a cartridge of brown paper.

1 2 is the space occupied by a wad of paper or wood, which forms the bottom of the cartridge.

2 3 is filled with powder, and contains an electrical cartridge 9, in which two insulated wires 7 and 8 are inserted.

3 4, a wad of paper.

4 5, about twelve inches of dry sand.

5 6, a pointed wooden plug, driven in with force so as to break the cartridge, and scatter the sand around the cone of the plug. The wires are laid in a groove of the plug to prevent abrasion.

10 is a common rail road spike, which is driven into the end of the plug, wedging it against the sides of the hole.

11 12, represents the line of the face of the rock.

FIG. 2

Represents another mode of blasting, invented by H. Haupt, and applied during the war to blowing down bridges. A rod of iron, one inch in diameter, and from eight to twelve inches long, is terminated with circular heads sufficiently large to fit the hole closely, but not too large to permit them to be inserted. A case of paper containing powder, surrounds the iron, and a hole in one end admits a fuse. An iron or brass cup, similar to that on the base of a rifled shell, serves as a gas check, to prevent the escape of the gas, and increase the effect of the explosion. The cup must be in two halves. No tamping is required. The irons are not often injured, and can be used repeatedly. Several holes can be loaded by one man in a minute. This plan cannot be used if the holes are not perfectly round.

FIG. 3

Is a cross section of the vacuum box, showing the longitudinal timbers, 1, 2, 3, 4, which support the floor; the floor boards, 5, 6, the track pieces, 7, 8, and the rails. Instead of the track pieces and flat rails, a light T rail may be substituted.

The floor boards should be tongued and grooved at the edges, but need not be planed. They are put together by first painting the edges of the boards with coal tar, filling the grooves with the

material; wet clay is rammed between the longitudinal timber 1, and the side of the tunnel, and also in the angle at 4, to prevent leakage between the timber and the rocks at the bottom.

FIG. 4

Is a longitudinal section of the vacuum box.

FIG. 5

Represents a section of one side of a stuffing box, showing a mode of packing to prevent leakage of steam. It consists in wrapping around the piston rod, several ribbon-like strips of material in the following order.

1. A strip of fine wire gauze.
2. Two or three thicknesses of cotton cloth dipped in tallow.
3. A strip of oiled silk.
4. India-rubber wrapped under tension, and to a sufficient thickness to fill the stuffing box, into which the packing is then pushed.

The width of the strips should be exact, so as to occupy the proper space in the stuffing box when wrapped.

The follower is bevelled as at (1) so as to press into and force outwards the India-rubber.

A groove (2) is turned around the stuffing box, and a small hole (3) admits steam, which pressing against the back of the packing forces it in contact with the piston.

The wire gauze in contact with the piston rod forms a metallic packing, and prevents rapid wear.

The rag coated with tallow assists to lubricate the packing.

The oiled silk prevents the grease from coming in contact with the India-rubber.

The rubber being impervious to steam, prevents its escape.

FIG. 6.

This stuffing box differs from Fig. 5, only in having a bevelled ring (1) against which the steam presses, instead of the recess. It has not been tested, but would probably be effectual.

FIG. 7

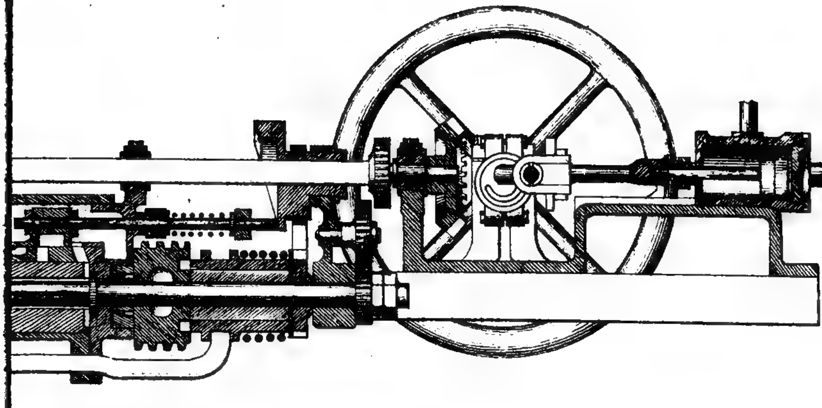
Represents a form of coupling for steam pipes.

A recess is turned in one pipe (1) into which a ring of vulcanized rubber is inserted; a projection (3) on the opposite end of the pipe fits into the recess, and forces the rubber ring inwards along its bevelled surface. A cap 4, 5, connects the ends of the pipes, and by turning it a short distance with a spanner, the ends are drawn together, and the sharp edge of one pipe faced into the gum in the recess of the other. There must be a projection on the cap, and a notch in the flange, to permit the two ends to be brought together.

FIG. 8

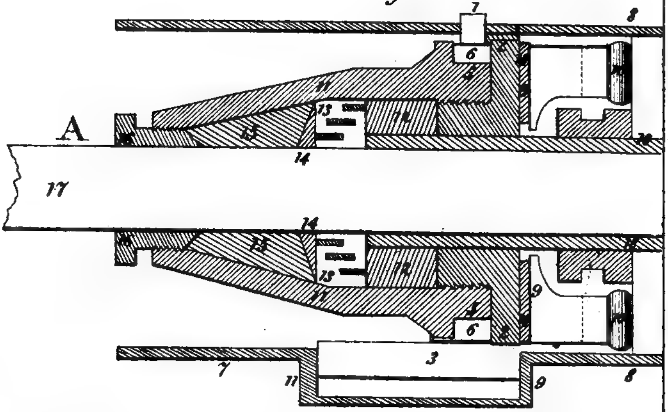
Is similar to Fig. 7, except that instead of the cap the joint is held by a couple of stout hooks, 1, 2.

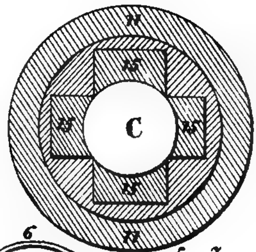
PLATE 1.

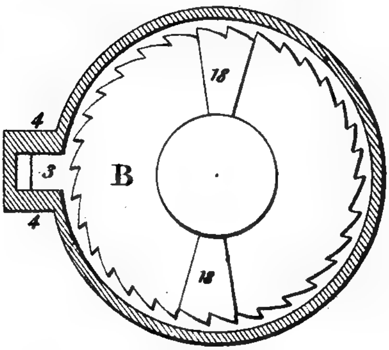


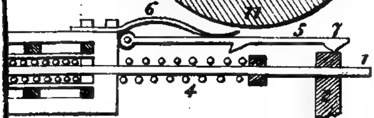
ve 7/8.

Fig. 4.









E. Herline, Lith. 630 Chestnut St. Philad^a.

DETAILS.

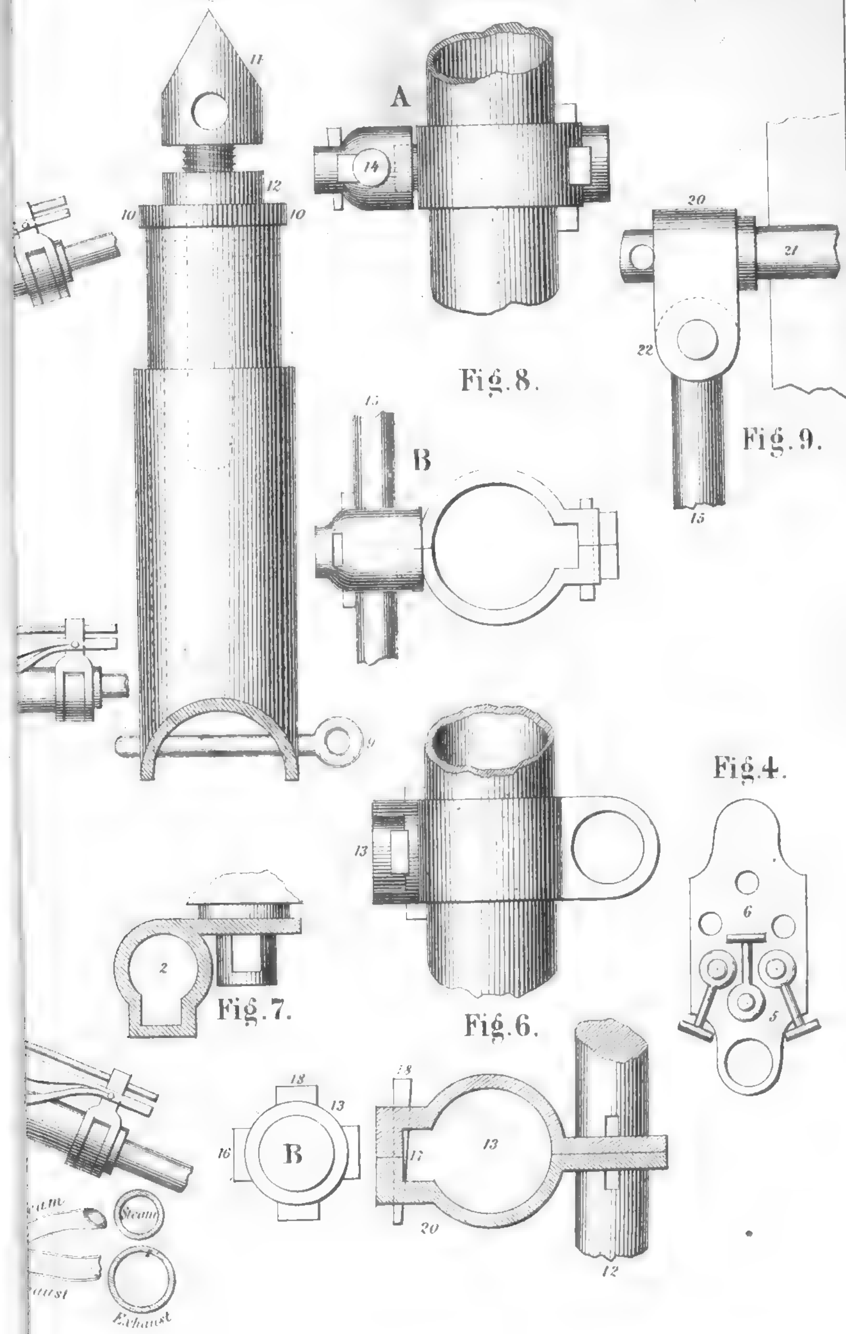
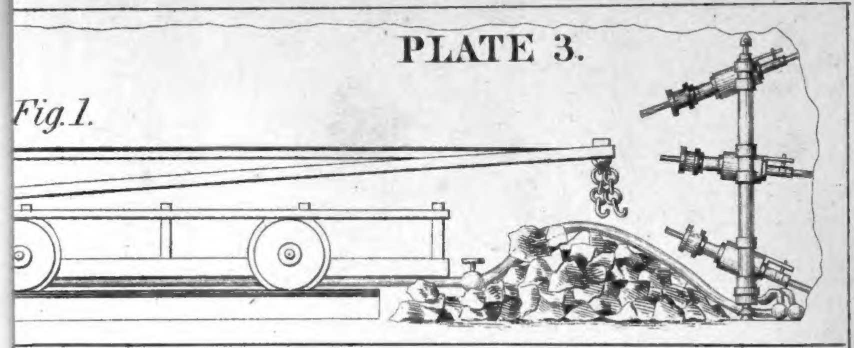


Fig. 5.
11
12
10
10
9
A
14
20
21
22
Fig. 8.
15
B
Fig. 9.
15
13
Fig. 4.
6
5
2
Fig. 7.
Fig. 6.
18
13
16
B
18
17
13
20
12
Steam
Exhaust

PLATE 3.

Fig. 1.



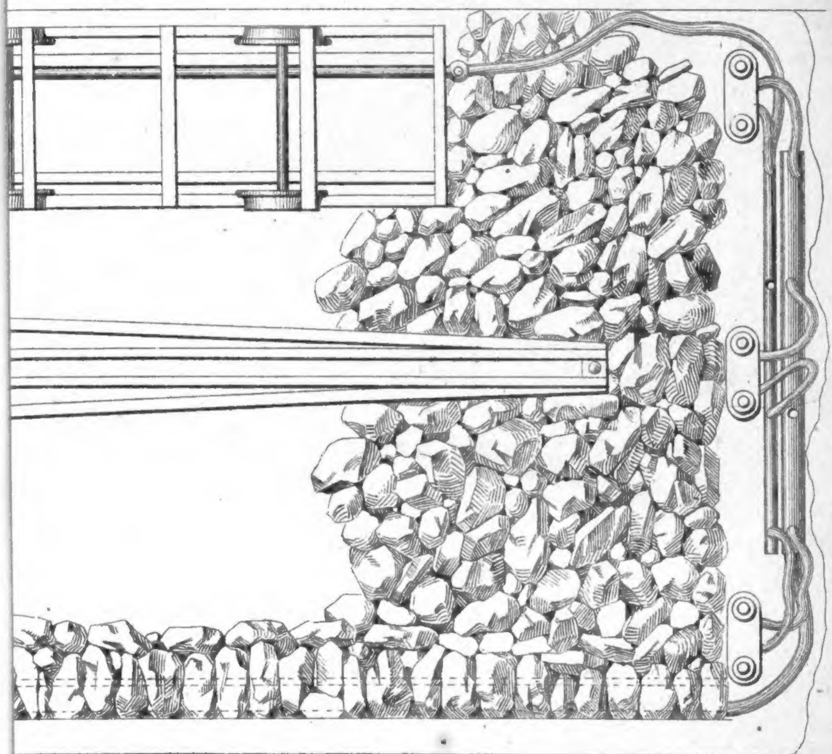


Fig. 4.

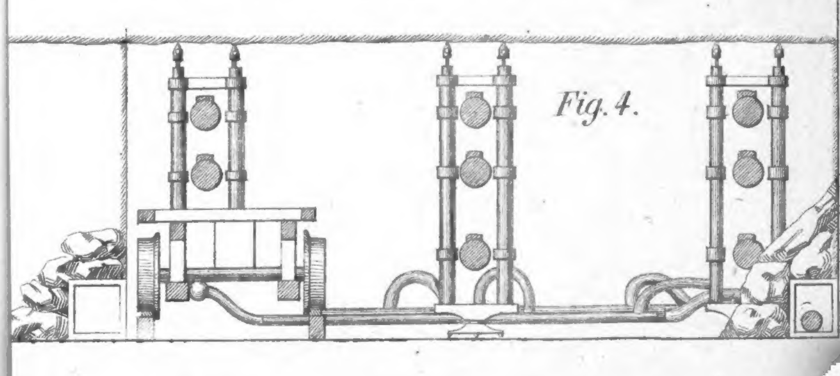


PLATE 4.

Fig. 1.

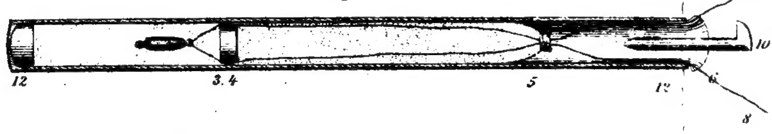


Fig. 2.

Fig. 3.

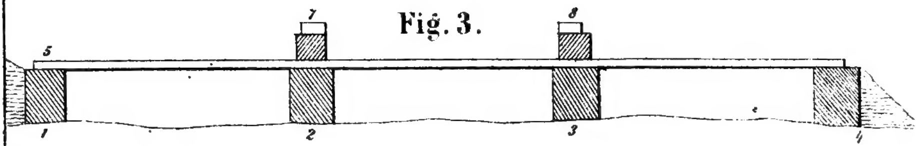


Fig. 4.

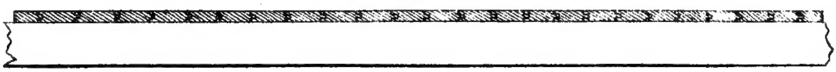


Fig. 5.

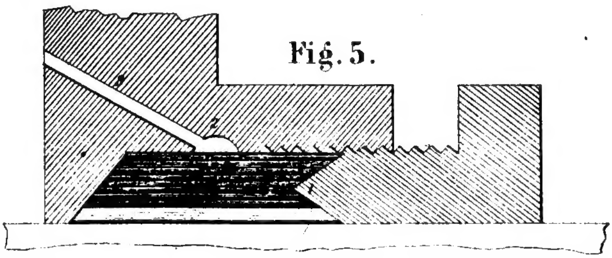
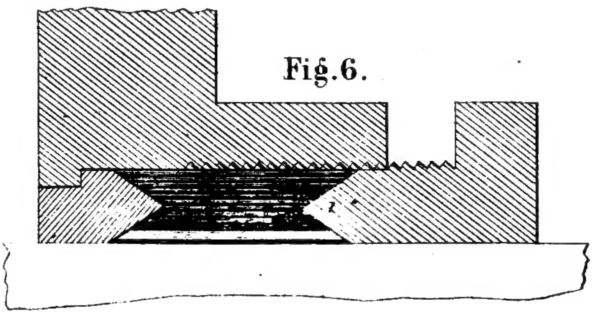


Fig. 6.



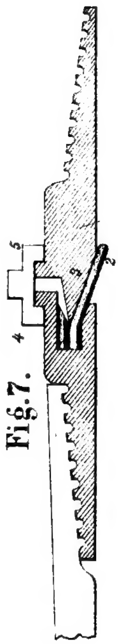


Fig. 7.

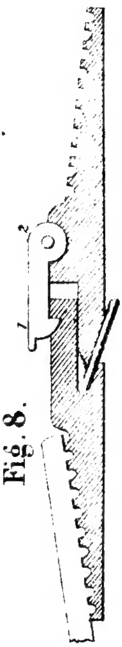


Fig. 8.

E. Herline Lith. 630 Chestnut St. Phila